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Spatio-temporal characteristics of some convective induced extreme events in Bulgaria

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Abstract: Severe convective storms produce dangerous weather phenomena esprcially during the warm half of the year like heavy and very intense rainfall, thunderstorms and hail-fall. They are often associated with strong to violent wind gusts and sometimes even with such dangerous events like squall or tornado. The objective of this work is to present the spatial and temporal distribution of torrential convective precipitations during the period 1991-2014 in different regions of Bulgaria. Only days in which there is thunderstorm activity combined with 24-hour precipitation amount above 60 mm are selected and analyzed. The choice of 60 mm/24h as a bottom limit is motivated by the fact that for 90% of all meteorological stations in Bulgaria it is equal or above the climatological monthly precipitation normal. The regional intra-monthly distribution of such extreme events is also presented and results for two 12–year periods 1991–2002 and 2003–2014, are compared and statistically estimated. Second part of the study summarizes general features of the tornado and waterspouts occurrence in Bulgaria (2001-2014) such as the geographical, monthly and diurnal distributions. Characteristics concerning tornado intensity are also presented.

Keywords: convective precipitation; tornado; climate; Bulgaria

1. INTRODUCTION

The aim of the present study is to continue the investigation over potentially dangerous severe storms that lead to abundant precipitation, to severe thunderstorms and hail, and rarely to such violent events as tornado. They are sparse in space and time and have unfavourable influence on the economics and societies causing significant property and infrastructure damages as well as losses of life.

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The first part of this study presents the spatial and temporal distribution of torrential convective precipitations during the last 24 years (1991-2014) in different regions of Bulgaria. Only days in which there is thunderstorm activity combined with 24-hour precipitation amount above 60 mm are selected and analyzed. The choice of 60 mm/24h as a bottom limit is motivated by the fact that for 90% of all meteorological stations in Bulgaria it is equal or above the climatological monthly precipitation normal. The regional intra-monthly distribution of such extreme events is also presented.

The distribution of precipitations across the territory of Bulgaria and its seasonality are mainly caused by the atmospheric circulation patterns and the topography characteristics. The zonal extension of the Stara Planina and the Rila - Rhodope massif present a natural barrier to the invasion of cold air masses towards the southern part of the country. These mountains are also a barrier to warm air masses that are forced to overflow them. Actually the country is divided into North and South Bulgaria by the Stara Planina mountain chain, which affects the precipitation and temperature regime on either side of it. However, a significant difference in the precipitation regime has recently been observed between the western and eastern parts of the country (Bocheva, 2015).

General features of the tornado and waterspouts occurrence in Bulgaria during the last 15 years are also presented. Second part summarizes their geographical, yearly, monthly and diurnal distributions. Characteristics concerning tornado intensity are also presented.

Tornadoes occur relatively rarely in Bulgaria compared to other parts of the world. These events 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.

2. DATA AND METHODS

The study is based on data of torrential convective precipitation events (days with $Q \geq 60$ mm/24h and thunderstorm) from the meteorological database of the National Institute of Meteorology and Hydrology (NIMH) of Bulgaria for the period 1991–2014. We consider all synoptic, climatological and rain-gauge stations, in which regular observations were completed during the whole period or part of it. Their number varies between 555 in 1991 and 371 in 2014. The records for duration and intensity of atmospheric phenomena are available for all cases. Expert quality control of data has been carried out. The automatic stations data is not included in this study, because of their short period of exploitation and different sensors. The distribution of stormy days for each station is analyzed and then summarized for each of the 6 considered regions in Bulgaria during the whole studied period. The selected regions are: North-West (NW), North-Central (NC), North-East (NE), South-East (SE), South-Central (SC), and South-West (SW) Bulgaria (BG) - see Fig. 1. They are chosen on administrative principle, but also match to some extend the different sub-climate zones of the country.

Intra-monthly distributions of convective torrential precipitations for each region, as well as annual and monthly distributions of large-scale convective storms for whole country are presented and results for two 12–years periods 1991–2002 and 2003–2014, are compared.

Statistical analysis is performed in order to assess the variability and possible differences in the torrential convective precipitation days from long-term data series. For the comparison of the two periods 1991-2002 and 2003-2014 ANOVA with Poisson distribution (StatSoft, 2004) are applicable to such discrete samples of heavy precipitation days.

The present work is based also on a collection of data of 55 tornados and waterspouts in Bulgaria between 2001 and 2014. 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, and the meteorological data base of NIMH and the archives of the Bulgarian Hail Suppression Agency (BAHS) are also included. The analysis of the vertical structure of the atmosphere at the location and the time of occurrence are based on the sounding data from the archives of NIMH. The tornado cases have also been classified by severity according the Fujita scale (Fujita, 1981).

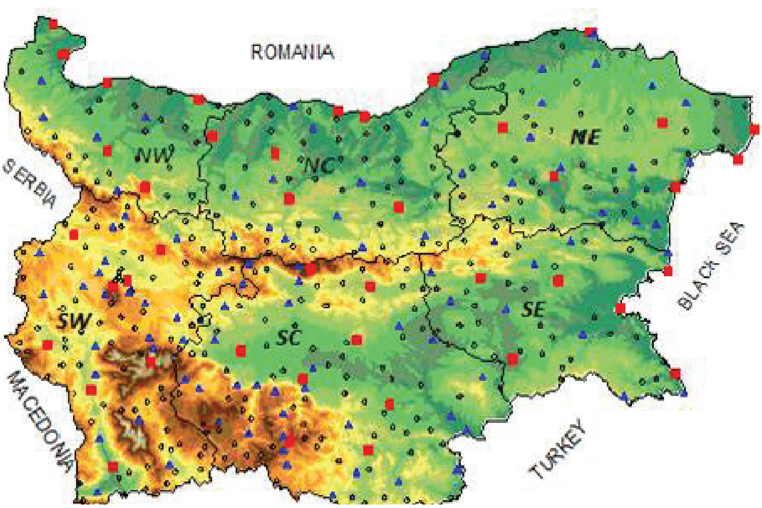


Fig. 1. The present NIMH weather stations network: synoptic (squares), climatological (triangles) and rain-gauge (circles) stations.

3. REGIONAL DISTRIBUTION OF CONVECTIVE PRECIPITATIONS

During the 24-year period of investigation the annual distribution of number of days with convective precipitation ≥ 60mm/24h shows an increasing trend almost in all regions although the number of meteorological stations in Bulgaria decreases. About 43% of days with dangerous precipitations during the period (1991–2002) are connected with convective storms (from 18.5% for SW Bulgaria to 55% for SC Bulgaria). During the second period (2003-2014) the contribution of torrential convective precipitations increases to 63% (from 40.3% for NC Bulgaria to 69.4% for SC Bulgaria). The increasing of number of convective heavy rain days is statistically significant for NE, SC and especially for SW Bulgaria (Table 1).

Table 1: Statistical comparison between two samples of number of convective precipitation days in different parts of Bulgaria, using the Poisson distribution for the 1991 – 2002 (1) and 2003 – 2014(2) data set.

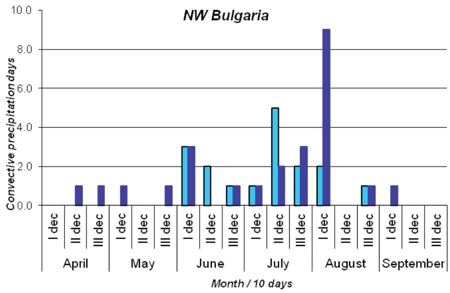
№ of samples	1	2	1, 2	tail	$(\mu_2 - \mu_1)/\mu_1$
Precipitation days	mean	mean		probability	
Group C2	μ_1	μ_2	$\chi2$	p	%
NW Bulgaria	1.4	2.1	1.533	0.216	0.46
NC Bulgaria	2.8	2.1	1.107	0.293	-0.24
NE Bulgaria	2.9	4.4	3.708	0.054	0.51
SE Bulgaria	3.8	4.4	0.495	0.482	0.13
SC Bulgaria	6.4	9.1	5.533	0.018	0.41
SW Bulgaria	1.7	4.2	13.28	0.0003	1.50

The maximum in annual distribution of stormy days is in the height of summer season in July almost for all regions in Bulgaria (Fig. 2). These results coincide with the observed maximum in monthly distribution of thunderstorm days for East Bulgaria (Bocheva et al., 2013) and are a month later than those for other parts of the country.

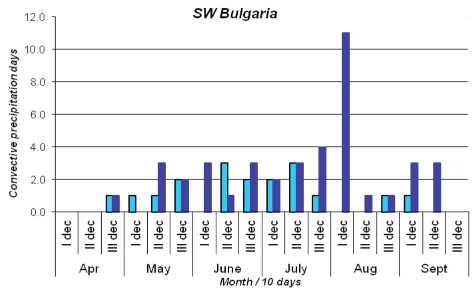
The comparison between two periods show differences in intra-monthly distribution of torrential convective precipitations in different regions in warm half of the year especially those from west and east parts of the country. During the second period (2003-2014) the maximum in such type event for the stations from West and SC Bulgaria is observed in first decade of August. In these regions the heavy thunderstorms become more frequent in all decades of September also.

For regions from north part of the country all such days occurred only during the warm season for whole period of investigation 1991-2014. Only in NE Bulgaria, a couple of torrential convective precipitations (bellow 10%), is observed during the second period 2003-2014.

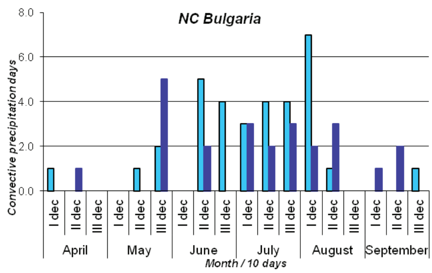
The potential dangerous precipitation events, attended by thunderstorms during the cold half of the year are typical for SC Bulgaria (about 40% of all torrential convective precipitations during the period 2003-2014) and to some extend for SE Bulgaria (26%) and SW Bulgaria (20%). This is connected mostly with the observed changes in atmospheric circulation over the region, especially with the changes in trajectories of Mediterranean cyclones over Balkans (Marinova et al., 2005). More than 80% of high-impact weather events over Bulgaria during the cold period of the year are associated with the behavior of Mediterranean cyclones and the great number of them affected south part of the country. Most Mediterranean cyclones associated with severe storms moved through the southernmost parts of Balkan Peninsula and for large part of motion was attended by a blocking regime in the mid-level mass field (Bocheva et al., 2007).



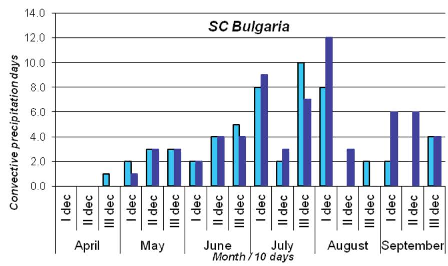
(a) NW Bulgaria



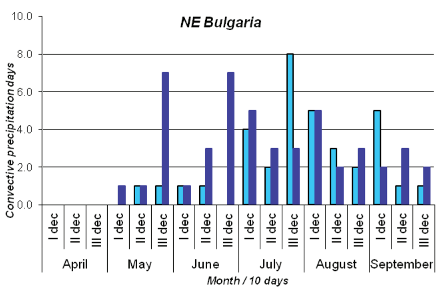
(d) SW Bulgaria



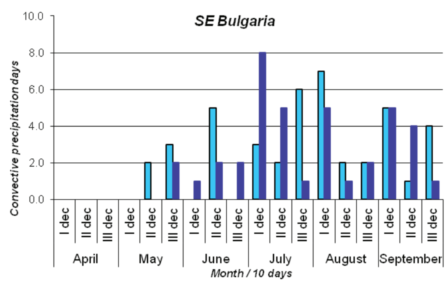
(b) NC Bulgaria



(e) SC Bulgaria



(c) NE Bulgaria



(f) SE Bulgaria

Fig. 2. Inter-monthly regional distribution of number of heavy convective precipitation days during the warm half of the year for periods: 1991-2002 (light blue) and 2003-2014(dark blue).

5. SPATIAL AND TEMPORAL DISTRIBUTION OF TORNADO EVENTS

All 55 tornado and waterspouts cases registered between 2001 and 2014 in Bulgaria have occurred in 44 days. The average number per year in Bulgaria is 3.9 which therefore makes up a frequency of P=0.35/10^4 km^2 $year^{-1}$. The similar frequency was published for Austria (P=0.3/10^4 $km^2 year^{-1}$ – Holzer, 2000) while the one for Greece appears to be 4 times bigger (P =1.1/10^4 $km^2 year^{-1}$ - Sioutas, 2011).

Only 18 out of 28 administrative regions have registered tornadoes for the 14-year period (Fig. 3). The Sofia-city region has the highest frequency of 2.1/10^4 $km^2 year^{-1}$ followed by Dobrich (1.2/10^4 $km^2 year^{-1}$) and Razgrad (1.1/10^4 $km^2 year^{-1}$).The regions of Varna and Burgas (0.7/10^4 $km^2 year^{-1}$), Plovdiv, Vratsa and Veliko Tarnovo (0.6/10^4 $km^2 year^{-1}$), Targovishte and Kyustendil (0.5/10^4 $km^2 year^{-1}$), and Smolyan (0.4/10^4 $km^2 year^{-1}$) exhibit frequencies greater than the national average. Only waterspouts have been reported in the region of Dobrich which border the Black sea.

All documented tornado cases in Bulgaria from 2001 to 2014 have been classified by severity according to the Fujita scale and by the type of the topography and the land use of the terrain upon which they occurred. There are 14 cases upon mountainous or hilly terrain covered by shrub or grass; 8 cases upon wooded mountainous or hilly terrain; 14 cases over flat terrain (plain); and 17 waterspouts. Almost half (above 40%) 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 (Giaiotti et al., 2007; Sioutas, 2011).

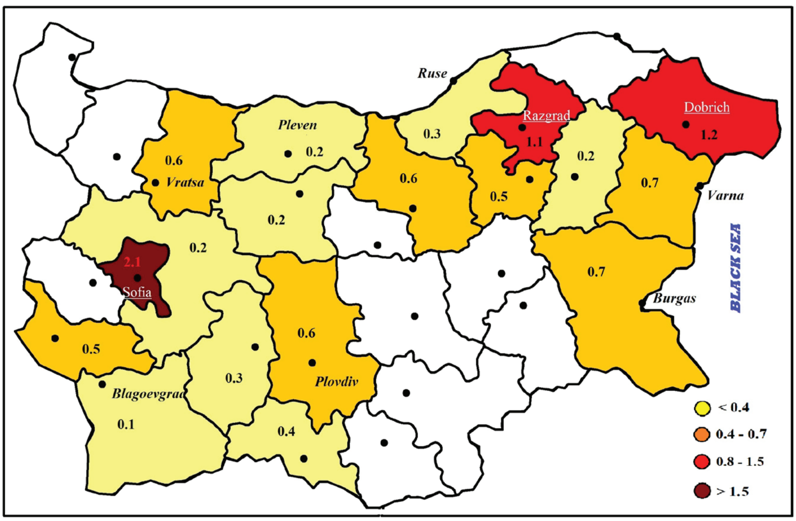
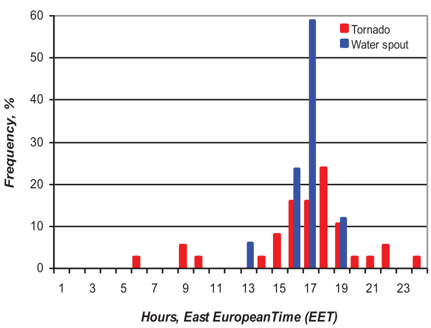


Fig. 3. Mean annual frequency of tornado occurrence in Bulgaria per administrative provinces (2001-2014).

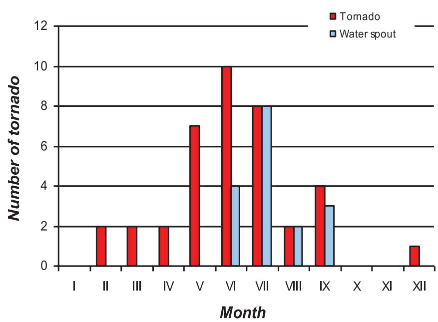
The classification by strength excludes the 17 waterspouts. The reason is that they caused no damage and this inhibits the attempts to classify them according to the Fujita scale. Most of the tornadoes (73%) match or even do not reach the F1 level of the Fujita scale which means that they were weak. About 11% of all cases 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 cases of a class higher than F2 in Bulgaria.

The diurnal distribution of tornadoes and waterspouts in Bulgaria show that most of the cases (about 80%) occurred within the afternoon hours between 15:00 and 19:00 Local time (East European Time (EET) which in summer is 3 hour ahead of the Universal Coordinated Time (UTC) and in winter – 2 h) – Fig. 4a. The monthly distribution of tornado cases (Fig. 4b) show that almost all cases (91%) occurred within the warm half of the year between April and September. The highest frequency of tornado events has occurred in June and July. This corresponds to the statistics for other countries in Central and Eastern Europe. Waterspouts in Bulgaria seem to occur between June and September. This matches the time of year when the sea water is the warmest.

In the list of documented tornadoes in the 14-year period there are 5 "winter" cases which occurred within the cold half of year: 3 of which in Southern Bulgaria and 2- in Northern 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.



(a)



(b)

Fig. 4. Diurnal (a) and monthly (b) distribution of tornadoes and waterspouts in Bulgaria (2001-2014).

CONCLUDING REMARKS

- Statistically significant recent increase in the number of days with torrential convective precipitation is observed in NE, SC and especially in SW Bulgaria.

- ❖ Tornadoes in Bulgaria mainly occur in the north-central, north-eastern and south-central regions of Bulgaria over mountainous terrain but also over plains.
- ❖ 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.
- ❖ In order to investigate more precisely the risk of severe hydro-meteorological events, it is necessary to build modern national database including the reported damage caused by the different hazardous events for the sectors of the economy. It can be done by restoring and unifying the available archive data in the insurance companies, the national civil-protection service, ministries, the national statistical institute, and others.

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REFERENCES

Bocheva L., Ch. Georgiev and P. Simeonov (2007). A climatic study of severe storms over Bulgaria produced by Mediterranean cyclones in 1990-2001 period. *Atmos. Res*., 83, 2-4, 284-293.

Bocheva, L., P. Simeonov, T. Marinova (2013). Variations of thunderstorm activity in non-mountainous regions of Bulgaria (1961 – 2010), *BJMH,* v.18, pp.38-46.

Bocheva L. (2015). Comparative analysis of heavy precipitation in non-mountainous regions of Bulgaria. 15th International Multidisciplinary scientific GeoConference SGEM 2015, Energy and Clean Technologies, Conference Proceedings, Air Pollution & Climate Change, 889-896, ISBN 978-619-7105-38-4, ISSN 1314-2704, DOI: 10.5593/sgem2015B41

Fujita, T.T. (1981). Tornadoes and downbursts in the context of generalized planetary scales. *J. Atmos. Sci*., 38, 1511-1534.

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

Holzer A. M. (2000). Tornado Climatology of Austria. *Atmos. Res*. 56, 203–212.

Marinova, T., L. Bocheva, V. Sharov (2005). On Some Climatic Changes in the Circulation over the Mediterranean Area. *Idojaras,* vol.109, No 1, pp.98-104

Sioutas M. (2011). A tornado and waterspout climatology for Greece. *Atmos. Res*. 100, 344-356.

StatSoft, Inc., STATISTICA (data analysis software system), version 6, 2004 (www.statsoft.com).