RECENT TRENDS OF THUNDERSTORMS OVER BULGARIA – CLIMATOLOGICAL ANALYSIS

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Abstract

Commonly the severe convective storms are not only attended by heavy rain events, but also by hail and thunderstorm activity, which on their own account cause material damages and life loses. According to Bulgarian Agency of Civil Defense and media the mean annual numbers of victims of thunders increased during the last years are about 10 people/per year

The aim of the study is to present time-space variations of thunderstorm events in Bulgaria during the period 1961-2010. Visual thunderstorm observations at 42 meteorological stations with altitude below 800 m are used in a study. By the orographic and climatic features the territory of Bulgaria are divided into 6 parts and thunderstorms annual, decadal and monthly distribution and variability is presented for each of them. The comparison of two investigated periods (1961–1990, 1991–2010) show that the mean number of registered thunderstorm days increase during the second period. This growth is statistically significant only in NE Bulgaria and partially in SC Bulgaria. The 75% of all thunderstorm days is observed in warm half of the year between May and August. In the same time the significant increase of thunderstorm events in all regions from North Bulgaria during the winter months December, January and February after 1991 is established. The regime of wide-spread stormy fays for 10-days period during the warm half of the year (April-September) is compared for the two periods: 1961-1990 and 1991-2010. The increase in number of those hazardous events during the months from the end of the summer is received.

Key words: *thunderstorm distribution, climate, Bulgaria*

1. INTRODUCTION

Thunderstorms and lightning are a major natural hazard to the aviation, power companies, wildfire management and to society as whole. Lightning cause great damages and dead every year, but also give us more information about the inner processes of convective storms. Thunderstorms themselves influence the climate system by redistribution of heat, moisture, and energy. So the investigation of thunderstorms generation, characteristics, distribution, etc. present a great interest for many researchers especially taking into consideration that there is an evident upward tendency of damages caused by natural disasters recently (IPCC, 2012). Much of them are caused by severe convective storms leading to torrential precipitation, hail, thunderstorms and strong wind events. Some authors (Easterling et al., 2000; Kothavala, 1997) point out that they occur with greater frequency, especially northward of 35°N. The same tendency is observed in Bulgaria during the last decade of the 20th century (Bocheva et al., 2006).

Thunderstorms can be registered automatically or visually. At present time more of thunderstorm observations are made automatically. Many authors in their studies use data from lightning detection networks (Katsanos et al., 2007; Petrova et al., 2009), or radar information (Horvath&Geresdi, 2001), or satellite products. The disadvantage of this type of data is the fact that the available data series are very short. Basically the usages of lightning detections systems date to the last decade of 20-thy century, some sensors were available only after 2000, and still there are many uncovered regions. So to study the thunderstorms climatology the only available data are those from visual observations made in meteorological stations (Changnon and Changnon, 2001; Bielec-Bakowska, 2003; Enno et al., 2012). The data for thunderstorms occurrence and duration go back for more than 100 years at many meteorological records, as well as in the meteorological archive of National Institute of Meteorology and Hydrology (NIMH) in Bulgaria.

According to media information and data from Bulgarian Agency of Civil Defense the mean annual numbers of victims of thunders increased during the last years and are about 10/per year. So are the thunderstorms over Bulgaria became more often or more violent recently, or both? This study presents regional distribution and changes of thunderstorm occurrences in non-mountainous regions of the country.

2. DATA AND METHODS OF INVESTIGATION

The study was carried out on the basis of meteorological data concerning thunderstorm events for 42 climatologic stations from the meteorological network of the NIMH for the period 1961–2010. These stations were representative for all geographical regions in the country with altitude below 800 m (Fig.1). The data series had been examined with respect to their quality and continuity of records. Expert quality control of data had been carried out.

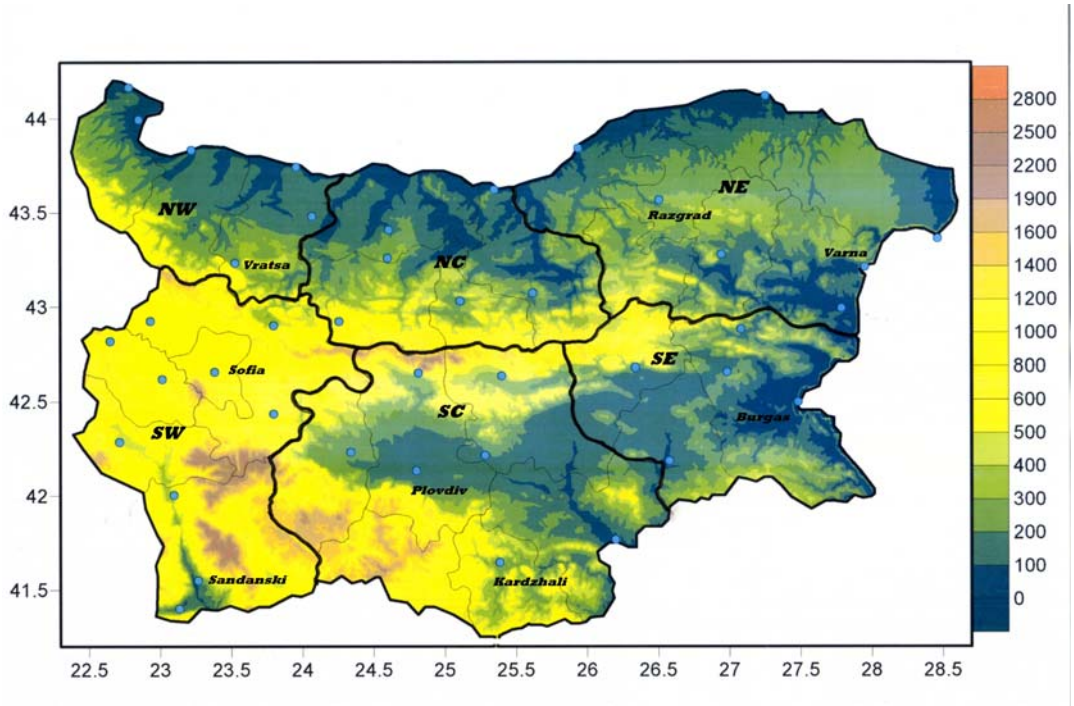


Figure 1. Climatological stations used in the study.

The territory of Bulgaria was characterised with very diverse relief. Also our country was located on the transition between two climatic zones – moderate continental and Mediterranean. By the orographic and administrative features we divided Bulgaria on 6 parts: North-West (NW), North-Central (NC), North-East (NE), South-East (SE), South-Central (SC), and South-West (SW) Bulgaria (see Fig.1). They were chosen basically on administrative principle but also matched to some extend the different sub-climate zones of the country.

All cases of thunderstorm occurrence at climatological stations during the studied period were investigated. A day with thunderstorm was accepted as a basic index for thunderstorm occurrence. The following criteria were used to define a day with thunderstorm:

- a day when at least one thunderstorm occurred between 00:00 and 24:00 h local time;
- the division into close and distant thunderstorm was not taken into account;
- if a thunderstorm occurred at the turn of 2 days, it was included into both days.

The data used in the analysis include the daily, monthly and annual number of the days with thunderstorms for every station and year. By specially developed Transact-SQL store procedures in Database Division of NIMH the annual and monthly distribution of days with thunderstorm for two periods (1961–1990, 1991–2010), as well as for large-scale storms were determined. According to Simeonov et al., 2009 as large-scale event a thunderstorm which was observed at least in 4 of the 27 districts in Bulgaria (more than 15% of the territory) in the same day were concerned.

Brief statistical analysis was applied for the assessment of variability and possible differences in the mean number of days with at least one thunderstorm event from long-term data series in each region. The statistical significance of their changes was calculated by the Mann-Kendall test for the whole period 1961-2010 (Package Kendall, 2008). For the comparison of the two periods 1961-1990 and 1991-2010 ANOVA with Poisson distribution (StatSoft Inc., 2004) were applicable to such discrete samples of thundery days.

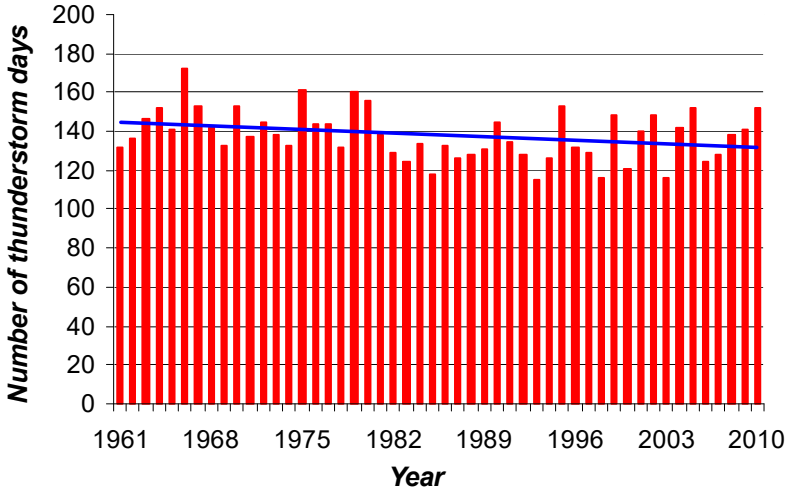


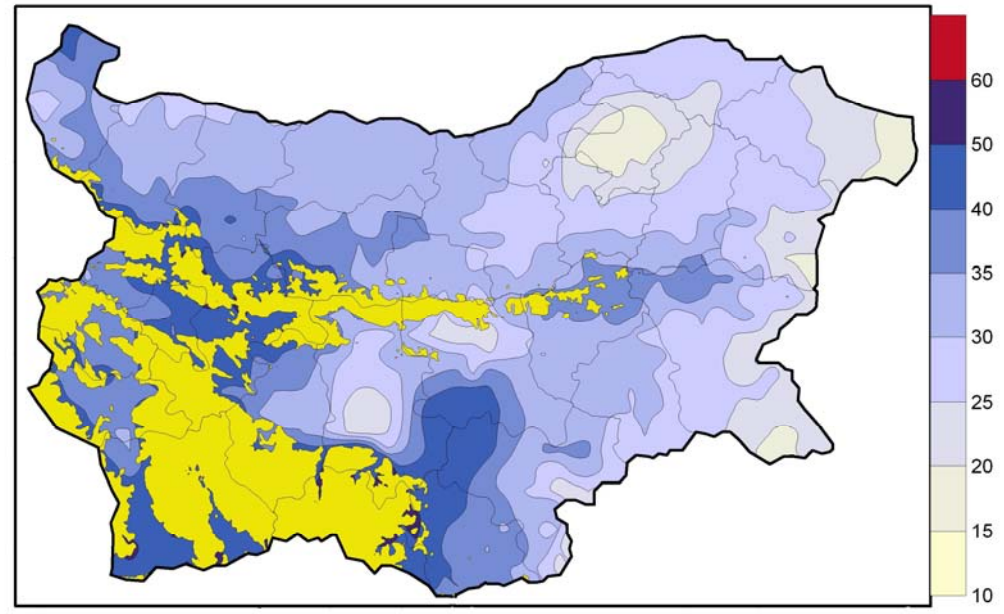
Figure 2. Mean annual number of thunderstorm days for the period 1961 – 2010.

3. ANNUAL DISTRIBUTION OF THUNDERSTORM DAYS

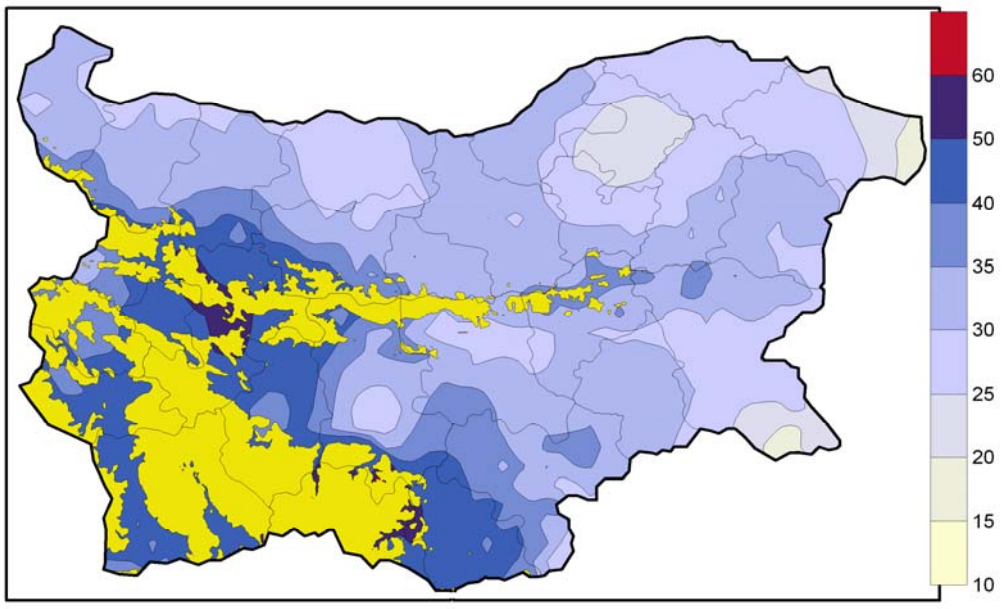
Slight negative tendency in annual distribution of thunderstorm days was observed for Bulgaria during the 50 years period of investigation (Fig. 2). The same was reported for some countries from Central Europe like Austria (Svabik, 2011), Germany (Kunz et al., 2009) and Poland (Bielec-Bakowska, 2003) as well as for central parts of USA (Changnon&Changnon, 2003). However, the applied Mann-Kendal test at 10% significance level for the annual number of thundery days for each region for whole 50-years period showed that the observed trends were statistically insignificant for the majority of the country. The significant increasing monotonic trend was received only for two regions – NE and SC parts of Bulgaria (see Table 1).

The results of the analysis of the number of days with thunderstorms at 42 stations all over Bulgaria in the period 1961–2010 showed that there were on average 30 days with thunderstorms in non-mountainous part of the country during the year, which coincided well with the results of Bielec-Bakowska (2003) for South Poland and with this of Simeonov et al. (1989) for non-mountainous parts of Bulgaria during the period 1956-1985. The spatial distribution of mean annual number of thunderstorm days for 2 investigated periods (1961-1990 and 1991-2010) was presented on Fig.3.

The annual number of thundery days depended on the region and varied from 10 days in East Bulgaria (Varna – 1981 and Burgas – 2003) and 68 days in SW Bulgaria (Sandanski – 1963). The highest number of days with thunderstorm occurrence was observed in mountainous SW Bulgaria where the mean annual number of days for 1 station during second period was 35 (Fig. 3b and Table 2). On the second place in distribution of thundery days were NW and SC regions with about 31 days. The lowest frequency of stormy days was detected in NE Bulgaria – an average 26 days in one station.



a) 1961-1990



b) 1991-2010

Figure 3. Distribution of mean annual number of thunderstorm days for each period: a) 1961-1990; b) 1991-2010.

The comparison of two investigated periods (1961–1990, 1991–2010) for different regions showed that the mean number of registered thunderstorm days increased during the second period for the most part of the regions, but the growth was not statistically significant (Fig.3 and Table 2). The statistically significant variation with about 15% was observed only in NE Bulgaria and partially in SC Bulgaria (with about 10%). For these parts of the country this fact was connected mostly with the observed changes in atmospheric circulation over the region, especially with the changes in trajectories of Mediterranean cyclones over the Balkans (Marinova et al., 2005).

Table 1. Statistical estimation for existence of monotonic trend, calculated by the Mann-Kendall test for the whole period 1961-2010 (Package Kendall, 2008)

Region	Mean	MIN	MAX	Tau	2-sided p value	Existence of significant linear trend
NW	32	18	53	-0.183	0.063	NO
NC	28	18	40	0.116	0.238	NO
NE	24	17	37	**0.213**	**0.031**	**YES**
SE	30	19	44	-0.040	0.688	NO
SC	32	21	49	**0.176**	**0.073**	**YES**
SW	36	24	53	0.002	0.987	NO

Table 2. Statistical comparison between two samples of mean regional annual number of thunderstorm days using the Poisson distribution for the 1961–1990 (1) and 1991–2010 (2) data set.

No. of sample	1	1	1	2	2	2	1, 2	tail	$(\mu_2 - \mu_1)/\mu_1$
Thunderstorm days	**mean μ_1**	**min**	**max**	**mean μ_2**	**min**	**max**	**$\chi 2$**	**probability p**	**%**
NW	32.7	16.2	53.2	31.4	23.5	40.7	0.67	0.414	-0.04
NC	27.5	17.7	39.8	28.8	17.8	38.8	0.83	0.363	0.05
NE	22.3	18.2	29.5	25.6	16.8	37.0	**5.58**	**0.018**	**0.15**
SE	29.7	18.6	42.8	30.4	18.6	44.2	0.18	0.675	0.02
SC	30.6	20.8	48.8	33.6	27.9	43.9	**3.27**	**0.070**	**0.10**
SW	35.5	23.8	53.3	35.8	25.1	47.1	0.04	0.851	0.01

4. MONTHLY DISTRIBUTION OF THUNDERSTORM DAYS

The analysis of mean monthly number of days with thunderstorms in all stations for whole country confirmed that usually about 75 % of all thunderstorms occurred during the period May – August. The maximum of thunderstorm activity was in June (Fig.4) when the mean number of stormy days was about 7 days/per station (maximum 12.0 days for Novo selo in NW Bulgaria and minimum 3.7 days for Varna in NE Bulgaria). Number of days increased in western and south-central part of the country near by the highest Bulgaria mountains: Rila, Pirin and the Rhodope Mountains, because of the preferable orographic conditions for convective initiation. In particular years the maximum number of thunderstorm days in June reached 18 – 20. The mean number of stormy days in May and July were almost equal during the first period (1961–1990), but during the second one (1991–2010) in July increased more rapidly (with about 16%) – Fig.4. The growth in thunderstorm occurrence recently was mostly due to the rise in observed stormy days in the second part of the summer (from July to September) and the most significant was this increment in September – with about 27%.

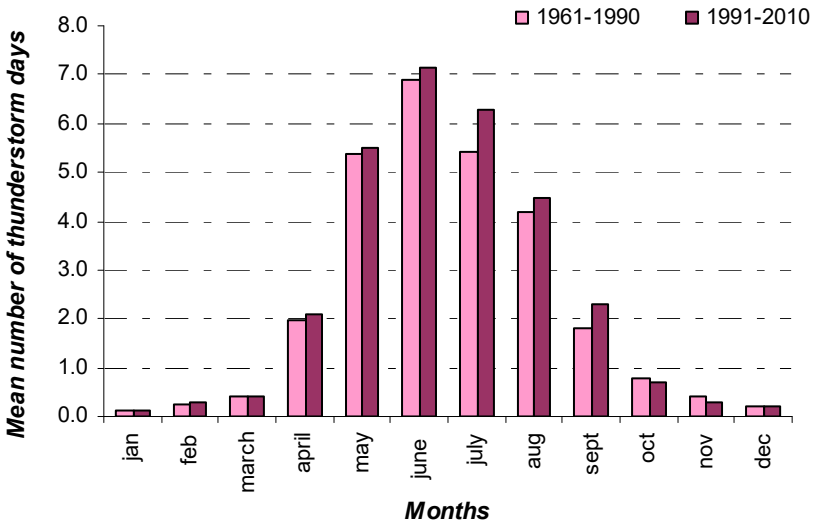


Figure 4. Mean monthly number of thunderstorm days for two investigated periods (1961-1990 and 1991-2010)

Monthly distribution of thunderstorm days in different regions in Bulgaria was the same for two investigated periods. The percentage deviation of mean monthly number of thunderstorm days during the 1991–2010 period towards 1961–1990 period, increased more rapidly in North Bulgaria (Fig. 5), especially in December and January – not typical for winter, but convective storms became more frequent at the present time.

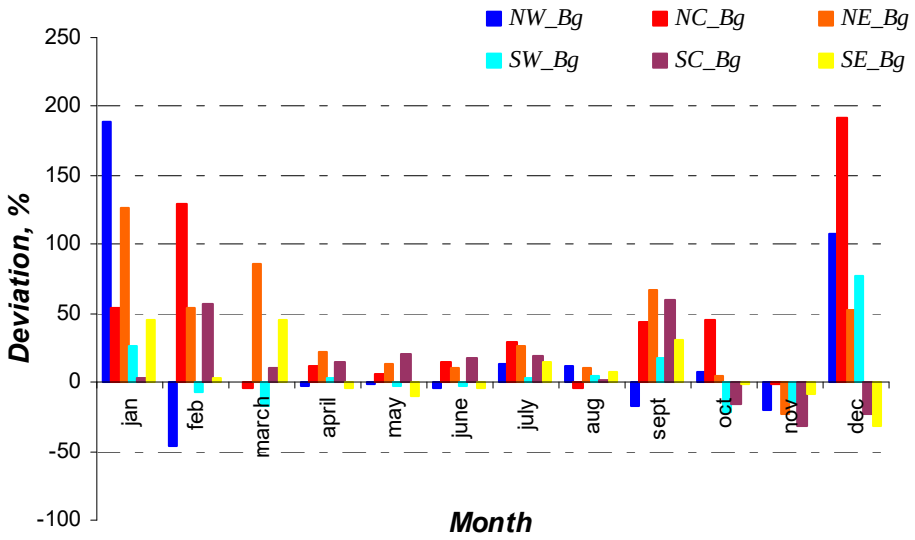


Figure 5. Deviation of mean monthly number of thunderstorm days during the 1991–2010 period towards 1961–1990 period

5. DISTRIBUTION OF LARGE-SCALE THUNDERSTORM DAYS

The detailed analysis of distribution of large-scale thunderstorm events, which affected at least 4 districts in Bulgaria was done. Taking into consideration that more than 85% of all thundery days for all regions were recorded during the warm half of the year, between April and September, the distribution of such type event only for this period of the year was presented below (Fig.6). The comparison of each decade of months from warm half of the year for two periods of investigation showed that no significant differences were observed. Large-scale thunderstorm events were more frequent between 3th decade of May and 3th decade of July where they were observed at least in half of all days in each decade. The increasing in number of large-scale thundery days was observed in 2nd decade of May (about 20%) and in 1st decade of August (about 30%) during the second period 1991-2010. The observation showed slightly decreasing tendency in the number of large-scale events during the months April-July for second period 1991-2010. In the same time the increasing in number of wide-spread stormy days an average with about 10% was observed in months August and September. As whole the number of observed large-scale thunderstorm days increase during the second half of warm season recently and in some decades this increment reached 20-32%.

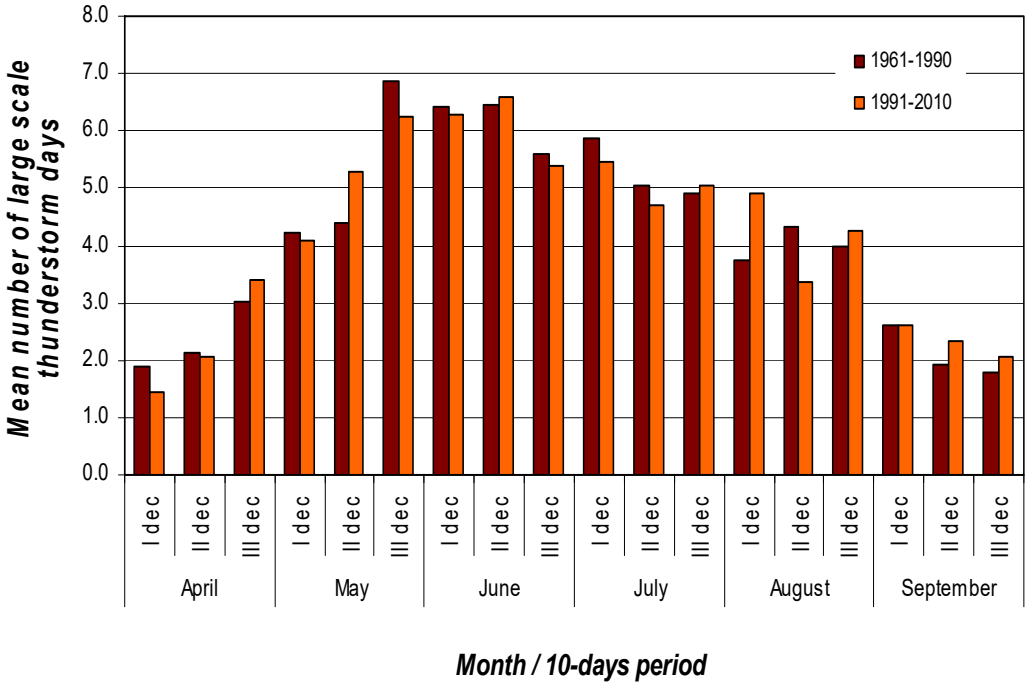


Figure 6. Monthly distribution of mean number of large-scale thunderstorm days during two investigated periods (1961-1990 and 1991-2010)

CONCLUSIONS

During the analyzed period (1961–2010), no statistically significant tendency was found in the annual and monthly distribution of number of days with thunderstorms in Bulgaria. The values in different parts of the country were typical for the climatic – geographical region in which Bulgaria is situated.

The comparison of distribution of thunderstorm days during the two periods (1961–1990 and 1991–2010) showed statistically significant increase in NE Bulgaria (15 %) and in SC Bulgaria (about 10%). In other regions of the country this increment was insignificant. Monthly frequency of mean number of stormy days for the two investigated periods did not differ much from each other. More remarkable were the observed growth in second part of the warm half of the year and especially in September with about 27 %. According to intra-monthly distribution of thunderstorm days recorded at least in 4

districts of Bulgaria, also the increasing tendency during the second half of warm half of the year was observed.

The changes in monthly regional distribution of thunderstorm days, particularly during the last 10 years, coincide with observed significant increase of torrential precipitation in NE and SE Bulgaria (Bocheva et al., 2009).

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