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

Wide-spread severe convective storm events in Bulgaria (1991-2010)

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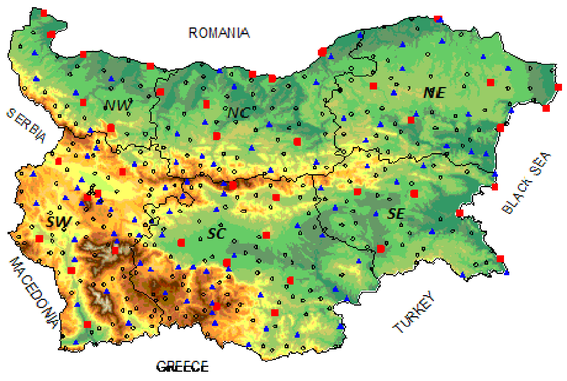
The objective of this work is to give an overview of the spatial and temporal distribution of the occurrence of severe convective storms (SCS) simultaneously in a large part of the country. The covered period is 1991-2010. All days in which there is thunderstorm activity combined with 24-hour precipitation amount above 30 mm are selected and analyzed. Detailed investigation is carried out on the part of these SCS which are observed in at least 4 out of 27 administrative regions of the country (see Simeonov et al., 2009). These large-scale SCS events have become more frequent in Bulgaria during the last 10 years. Most of them (96 % of all) have also been documented as being the cause of floods and economic loss in the affected regions. They are more often found in Central and East Bulgaria than in the western part of the country. 80% of them occur in the second half of summer and the first half of autumn.
An attempt is made to classify the synoptic situations leading to such type of massive SCS in Bulgaria and to further investigate the frequency distribution of the derived synoptic types on annual and monthly basis.



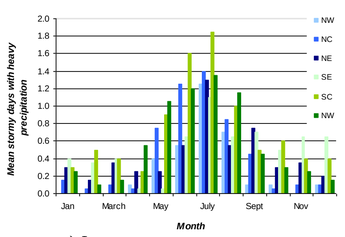
The present NIMH weather stations network: synoptic (squares), climatological (triangles) and rain-gauge (circles) stations

The distribution of 2 groups 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 chosen groups are: ***group I*** – days with heavy precipitation (59.9 ≥Q≥ 30 mm/24 h) and thunderstorm (Ts) at least in one station; ***group II*** - days with torrential precipitation (Q≥ 60 mm/24 h) and Ts at least in one station. 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). They are chosen on administrative principle but also match to some extend the different sub-climate zones of the country. The Table, presented on the right, summarizes the geographical features of the six regions.
Annual and monthly distributions of large-scale SCS are presented and results for two 10–year periods 1991–2000 and 2001–2010, are compared.
The NIMH historical archive of synoptic maps and NCEP/NCAR Reanalysis data and maps were used for the analysis and classification of synoptic situations causing severe convective weather events at least in 15% of the territory of Bulgaria. Maps are produced on http://www.esrl.noaa.gov/psd/ (NOAA/ESRL Physical Sciences Division, Boulder Colorado) and are based on NOAA Reanalysis (Kalnay et al. 1996).

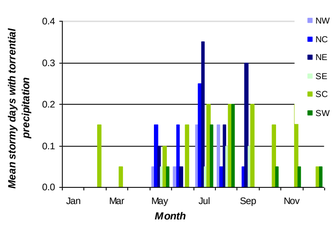
Geography of regions	Orography	Relation to sea bodies
NW Bulgaria	Flat, mountain ridge at southwest border	Far from sea
NC Bulgaria	Flat, mountain ridge at south border	Far from sea
NE Bulgaria	Flat, mountain ridge at southwest corner	Borders the Black Sea
SE Bulgaria	Flat, low mountain at south border	Borders the Black Sea, close to Aegean Sea
SC Bulgaria	Flat in the middle, mountainous massive in the south, mountainous ridge in the north	Closest to Aegean Sea
SW Bulgaria	Very mountainous	Close to Aegean Sea

DISTRIBUTION OF SEVERE CONVECTIVE STORMS

Regional monthly distribution of SCS



a) *I group*



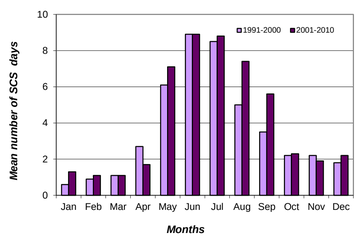
b) *II group*

Half of all heavy precipitation events attended by thunderstorm activity or/and strong winds.

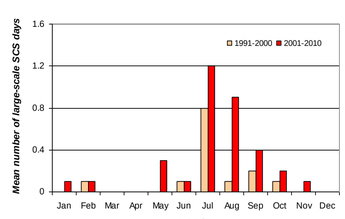
The maximum in the annual distribution of stormy days is at the height of the summer season in July for all regions in Bulgaria. For cases from group I this result coincides with the observed maximum in the monthly distribution of thunderstorm days for East Bulgaria. It takes place a month later than for other parts of the country (Bocheva et al., 2013).

For regions from North Bulgaria all days from group II occur only during the warm half of the year during the studied period. In the same time they are typical for SC Bulgaria (about 40% of all cases take place in winter). Some cases from group II are observed in SW Bulgaria from October to December (first half of the cold season).

Distribution of wide-spread SCS



a) all cases of SCS



b) Only wide-spread SCS

The inter-annual distribution of the mean number of days with SCS is presented. There is difference in the number of thundery heavy-rain days during the two investigated periods. While during the first decade (1991–2000) the greatest number of SCS days in one station is observed in June, July and May (a), in the second decade (2001–2010) such type of events more frequently occur in all summer months. In August and September their increment is statistically significant (about 50–60%). It can be said that as a whole SCS days increase during the second period with about 14%. Only in April statistically significant decrease of SCS days with 37% is observed.

For the whole contry there is observed increase of the frequency of the large-scale SCS episodes in almost all months during the 2001–2010 period (b). There is growth of about **140%** on annual basis. It is most significant in August (8 times more than during the period 1991–2000). August is followed by September and October in which there have recently been observed two times more massive SCS.

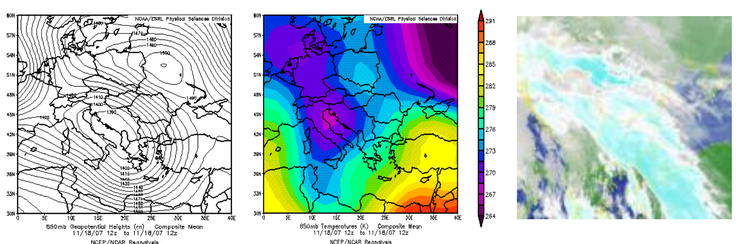
WEATHER PATTERNS ASSOCIATED WITH SCS IN LARGE PART OF BULGARIA

Region/Season	Spring	Early summer	Late summer	Autumn	Cold season
NW Bulgaria	1	**13**	**5**	3	0
NC Bulgaria	1	**11**	**7**	3	0
NE Bulgaria	1	7	2	**6**	0
SE Bulgaria	2	8	1	**5**	**2**
SC Bulgaria	**4**	**11**	**4**	**5**	**2**
SW Bulgaria	**4**	**10**	**6**	**6**	**1**

Thunder activity in Bulgaria is typical for the warm season from mid April to mid October. It reaches its maximum in June (Bocheva et al., 2013). However the data suggest that heavy rain on a large part of the country and associated with thunder occurs more frequently in July, August and even September than in June. Occasionally heavy rain with thunder may occur in the cold season from mid October to mid April too.
We define 5 different periods as it concerns heavy rain with thunder: spring (May-June); early summer (July), late summer (August); autumn (September-October); and cold season (November-April).

1. Cold season (November – April)

Typically the weather pattern providing heavy precipitation in the cold season is a classic Mediterranean cyclone passing by the country in different trajectories. When it leads to heavy rain with thunder though we need 2 conditions: **I** - the cyclone should be positioned to the southwest of the country and the southeast of Bulgaria should be in the warm air where temperature at 850 hPa geopotential surface should be above 0ºC. Warm air is needed in order convection to take place in this unfavorable season; **II** - the cyclone may move along its usual way to the northeast, however it should pass rather to the northwest of Bulgaria or occasionally through the country. This provides continuous southwestern flow over southeastern Bulgaria which is to guarantee the influx of warm and humid air from the Aegean Sea into Southeast Bulgaria. **Example - the case of 18 November 2007**.

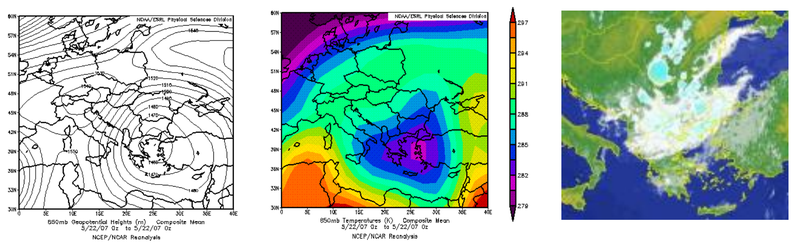


a) 850 hPa geopotential height (m) b) 850 hPa air temp. (K) c) IR satellite image.

d) Flood in Sofia f)Flood near by Svilengrad

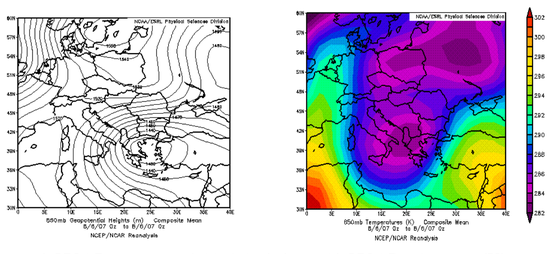
2. Spring (May-June)

When large area of the country is hit by heavy rain with thunder in spring this is typically associated with general unstable conditions. In spring the soil and vegetation are still moist and provide sufficient amount of moisture at place to feed convection. Therefore complex large-scale synoptic weather patterns are not needed to supply moisture from the Mediterranean. Large and smooth area of relatively low pressure at height together with relatively cool air is enough to provide conditions for wide-spread convection in the country. Thus the accumulated precipitation amounts may reach the target in more than 4 administrative districts. Often however there is an upper low positioned to the south or southeast of Bulgaria. In addition it provides so that the convective systems flush themselves out easier when trying to overcome an orographic obstacle from the northeast. The southwest and south-central parts of the country are the most mountainous and provide such obstacles. **Example - the case of 21-22 May 2007.**

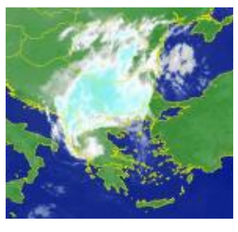


a) 850 hPa geopotential height (m) b) 850 hPa air temperature (K) c) IR satellite image.

d) Flood in Vladaya, Sofia district f) After tornado in Kalekovets, Plovdiv district



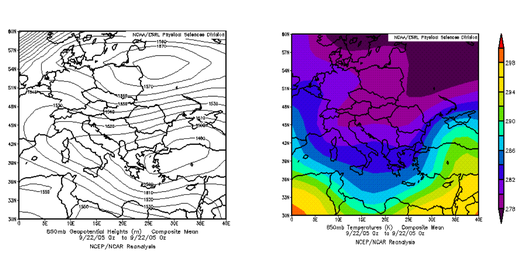
a) 850 hPa geopotential height (m) b) 850 hPa air temp. (K)



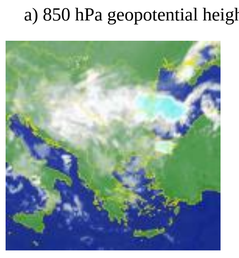
c) IR satellite image. d) Flood in Tsar Kaloyan village, NE Bulgaria

3. Summer (July-August)

When relatively small cyclonic systems, born in the Mediterranean to the south of the Alps and cut off the Polar front, move into the West Balkans and become stationary they produce powerful meso-scale convective systems, particularly over the mountainous central Balkans including West and Central Bulgaria. The convection feeds back the cyclonic circulation with fresh energy and thus sustains the strong precipitation for a couple of days. The low should be positioned either to the west of Bulgaria or over the country. Such cyclone eventually moves eastwards and provides conditions for heavy rain there too. **Example - the case of 6 August 2007.**



a) 850 hPa geopotential height (m) b) 850 hPa air temp. (K)

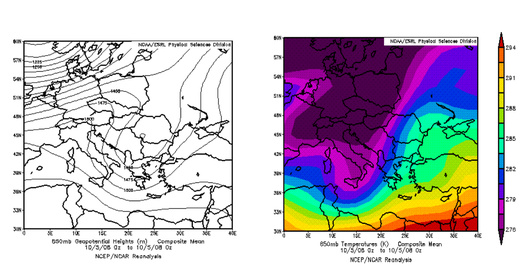


c) IR satellite image. d) After flood in Shabla, Black sea coast

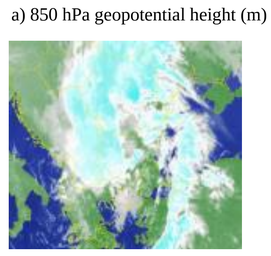
4. Autumn (September-October)

Convection systems a mostly generated over sea and then transported inland by the dominant mid-troposphere flow. The low can be positioned either to the west or over Bulgaria. But it should best be over the eastern part of the country or over the Black Sea. This position favors the development of convection over the warm sea. The convective systems then move inland and flush the eastern regions of Bulgaria. **Example - the case of 21-22 September 2005 (left).**

The southwest and south-central regions are also menaced by heavy rain in autumn. This however happens differently than the case for Eastern Bulgaria. In autumn the frequency of Mediterranean cyclone increases and the days with heavy rain in a large part of the country become more frequent too. However if they are to be associated with thunder they should be rapid and passing through the country rather than to the south. **Example - the case of 5 October 2008 (right).**



a) 850 hPa geopotential height (m) b) 850 hPa air temp. (K)



c) IR satellite image. d) Flooded railway lines in SC Bulgaria

Conclusions:

The results from the analysis of SCS, registered in the meteorological network of NIMH for the period 1991-2010 can be summarized as follows:

➢**The month of June is the one with most frequent thunder activity. However it is the month of July when the thunder activity is the most associated with heavy rain in large part of the country.**

➢**The different regions of Bulgaria are endangered by heavy rainfall with thunder in different seasons. Our classification of weather patterns and dangerous seasons can be used as input information for decision making to improve preparedness for heavy precipitation events with thunder.**

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