VARIABILITY AND TRENDS OF EXTREME PRECIPITATION EVENTS OVER BULGARIA

Lilia Bocheva, Tania Marinova, Petio Simeonov, Ilian Gospodinov

, National Institute of Meteorology and Hydrology-BAS, 66 Tsarigradsko Chaussee, Sofia-1784, Bulgaria

Lilia.Bocheva@meteo.bg, Tania.Marinova@meteo.bg, Petio.Simeonov@meteo.bg, Ilian.Gospodinov@meteo.bg

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I. INTRODUCTION

Global warming is suggested to be linked to the recent increase of heavy rainfall events due to the increased atmospheric water vapor and warmer air. Annual precipitation totals also show upward trends in many regions (Dai et al., 1997). Contrary to many mid- to upper latitude regions of the world in which the positive trends in precipitation amounts were reported, several studies (Alexandrov et al., 2004; Sharov et al., 2000), show a dominant downward trend in Bulgaria. In most areas of the world, the trends in rainfall have the same sign as the trends of 1-day heavy rain amounts. The series of hazardous events which affected the Balkans and in particular Bulgaria in 2005 are connected with severe convective storms and really heavy rainfall events which produced floods in more than 80% of the territory of the country and caused significant property damage, (more than half a billion EUR) loss of life (25 victims) and had a considerable impact on the Bulgarian economy. Gathering and analyzing all the available data for such type of weather phenomena is therefore necessary in order to improve their predictability.

II. METHOD OF INVESTIGATION

Meteorological data from the database of the Bulgarian National Institute of Meteorology and Hydrology (NIMH) from 65 climatological and 26 precipitation stations below 1000 m of altitude, for the period 1961-2006, have been processed.

The inter-monthly (by decades) distributions of the mean number of days with potentially dangerous precipitation (totals over 30 mm/24 h are considered to be flood risky) registered at least in 4 districts of the country, have been obtained. The results for the periods 1961-1990 (accepted as a basic period) and 1991-2005 have been compared. In order to show the contribution to observed annual totals of heavy/torrential rain, 5 daily rainfall categories have been suggested (as percentage of the total annual amounts) as follows: Light (A) 0.0-4.9 mm; Light-Moderate (B) 5.0-14.9 mm; Moderate-Heavy (C1) 15.0-29.9 mm; Heavy (C2) 30.0-59.9 mm and Torrential (D) 60.0 mm and above. The risk of extreme precipitation seasons during the studied period (1961-2005) is assessed by means of general statistical approach applied for each single value *i*: $X_i \geq X_{mean} + 2\sigma$, where X_{mean} is the mean value of the variable X (for example, mean long-term value), σ is the mean deviation from the mean value.

The NIMH's historical archive of synoptic maps and NCEP/NCAR Reanalysis have been used for analysis and classification of the synoptic situations causing heavy rain and damage in at least 4 districts of the country. Two typical situations (winter and summer case from the extreme year 2005), associated with extremely severe weather and damages in a large part of the country have been analyzed following the approach of Simeonov and Georgiev, 2003.

III. RESULTS AND CONCLUSIONS

A study of the long-term distribution of the average precipitation totals (Q_i) for the entire territory of the country has been carried out. Figure 1 shows the distribution of the average annual precipitation sums with the accepted limit (Q_{mean}+ 2σ) and it brings to evidence the extreme cases (Simeonov et.al., 2006). In this 45-years period there are 3 extremely wet years: 1966, 2002, and 2005.

The long-term distribution of the annual precipitation sums of the heavy-rain days only, selected and calculated by the above-mentioned criteria, shows an upward trend. The rainiest season is 2005, followed by 1966 and 2002 (Fig.2). An increase of the mean annual number of days with extreme precipitation (with about 33% during the period 1991-2005 in comparison with 1961-1990) can be identified whereas the annual rainfall sums as a whole decrease. A similar feature has been pointed out in Alpert et al., 2002 for other Mediterranean countries as well.

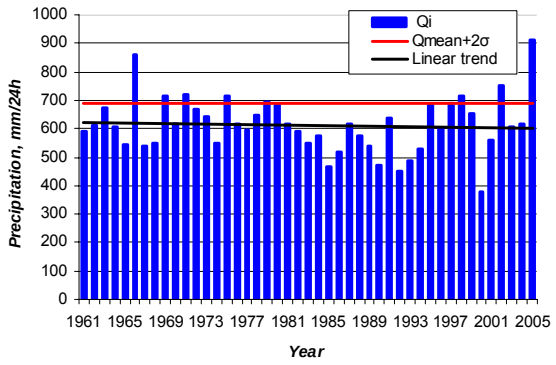


FIG. 1: Distribution of the mean precipitation totals for the period 1961-2005 highlighting the extreme events.

The mean number of heavy-rain days per year for the entire period 1961-2005 is 15. For the period 1991-2005 there are nine years above that average whereas there is less for the entire reference period 1961-1990.

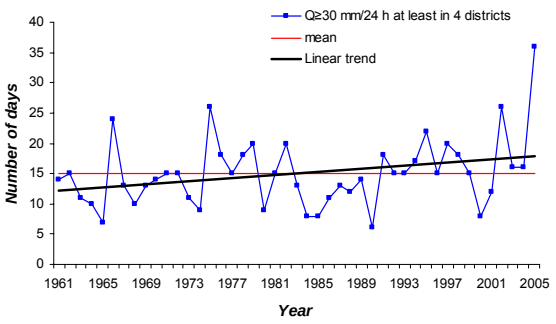


FIG. 2: Distribution of heavy-rain days during the period 1961-2005.

The contributions (as percentage of the total annual amounts) of each of the above defined rainfall categories for the period 1961-2005 are shown in Fig.3. The heavier categories, C1, C2, and D, see their contribution to the total increased during the recent decades in expense of categories A and B.

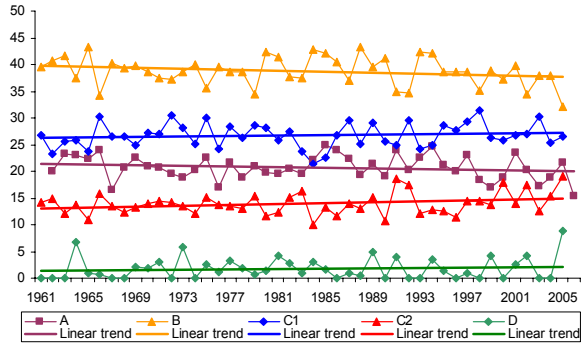


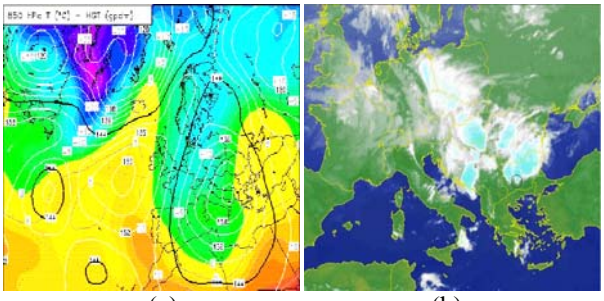
FIG. 3: Rainfall contributions, as percentage of the total annual amounts, for each of the rainfall categories A, B, C1, C2, D.

Synoptic classifications

There are 676 days with heavy-rain events in at least 4 districts for the entire period 1961-2005. The synoptic situations, associated with those events, have been studied and classified.

We give here briefly a description of two cases: an exotic one of severe winter thunderstorms on 14-16 February 2005 and a heavy-rain thundery hailstorms on 30 June-3 July 2005. In both cases there are reported tornado-like events.

On 13 and 14 February 2005 a cold air sinks into the Western Mediterranean and generates a cyclone over Italy. The air transport over the Balkans therefore turns northwards and strengthens. It brings warm and humid air alongside the cold-front line associated with the Mediterranean cyclone and crossing Bulgaria northeastwards. The conditions are therefore favorable for the generation of rapidly moving northeastwards convective systems which indeed materialize in the Rodopi Mountain in the southeast corner of the country on 15 February (see Fig.4a). Those systems bring heavy thundery downpours in the region together with gust winds and tornado-like whirls.



(a) (b)

FIG. 4: Temperature and geopotential at 850hPa at 12 UTC on 15 February 2005 (a) and Meteosat IR satellite image at 22h UTC on 1 July 2005 (b). The Cb cloud associated with the tornado is circled.

On 30 June-1 July there is a well defined polar front with zonal extend to the north of Bulgaria. It dominates the circulation. To the south of the polar front there are lingering patches of an old frontal system which dictated the weather in Western Europe a couple of days before but lost momentum. Now its remains are being sucked by the polar front northeastwards. One of them crosses Bulgaria during the night from 30 June to 1 July and generates thunderstorms across the country and than moves away into the Black Sea. However, on 1 July, the backside part of that system stretches diagonally through the country from northwest to southeast. A new series of thunderstorms pop up alongside that line in the late 1 July and move northeastwards with the predominant mid-troposphere flow. The southernmost of them generates in the West Rodopi Mountain (See Fig.4b). The complex mountainous terrain along its path favors apparently the generation of a tornado-like whirl.

Conclusions

- There is an evidence of an increase of the number of days per year with extreme precipitation (about 33 % during the period 1991-2005). This result is even more striking within the overall decrease of the total annual rainfall.
- The frequency of heavy-rain events within the warm half of the year for the last decade is about 60% higher compared to the reference period 1961-1990.
- The two studied cases suggest that winter and summer storms alike now bring more frequent tornado-like events which are emerging as an important life and property threatening meteorological phenomena in Bulgaria throughout all seasons.

IV. REFERENCES

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