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EXTREME PRECIPITATION MONTHS AND PRECIPITATION INDICES FOR NORTHEASTERN BULGARIA ON THE BACKGROUND OF CLIMATE CHANGE

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Increasing of the frequency of the extreme meteorological events in the last years is considered as one of the consequences of climate change. Extreme weather and climate events have received increased attention in the last years due to their impact on different aspects of human activity.

The aim of the present research work is to bring to better understanding the features of extreme precipitation occurrence in Northeast Bulgaria. Extreme wet months and extreme precipitation indices are investigated. Extremely wet months are defined as months with total precipitation amounts higher than 90% percentiles of the empirical distribution of the data. The occurrence of extreme precipitation is analysed by calculation of precipitation indices as number of wet days, maximum number of consecutive wet days, simple daily precipitation index, and heavy and very heavy precipitation days.

The knowledge on spatial and temporal occurrences of extremely wet months will help for further developments of various strategies for mitigation and adaptation to climate change and for effectively tackling environmental problems.

Key words: extreme precipitation, Bulgaria, precipitation indices, circulation indices.

INTRODUCTION

Precipitation is a key element which determines the availability of water resources. The changes in regime and quantity of precipitation affects the hydrological cycle. Hartmann et

al., 2013 point out the statistically significant trend of the precipitation in the mid-latitudes of the northern hemisphere (30°N to 60°N) for the 1901 to 2008 while for the shorter period (1951–2008) the trends are also positive but non-significant. Nevertheless, in regional and local scale the tendencies can be different. The projections given by IPCC (2013) show that extreme events are very likely to be changed in relation to their intensity and location in the 21st century. Casanueva et al. (2014) associate these changes with climate dynamics over various regions of Europe. A significant increase in the occurrence of extreme phenomena such as heat waves, drought and intense rainfall has been observed in Europe (Beniston et al., 2007, Lenderink and Van Meijgaard, 2008).

The tendencies in recent climate change in Bulgaria has been investigated by many authors (Vekilska and Rachev, 2000; Topliiski, 2005; Velev, 2002, 2006; Alexandrov et al, 2004, Alexandrov, 2010; Drenovski and Stoyanov, 2010; Nikolova, 2014 etc.). The extreme precipitation has been analyzed by Penkov (2002), Velev (2005), Chenkova (2010), Nikolova (2014). Since the mid-1990s, the trend of annual precipitation has been positive for most regions of Bulgaria. According to Bocheva et al. (2010) a considerable increasing of average days with daily precipitation amount above 100 mm has been established for the period 1991–2007 in comparison to 1961–1990. Nikolova (2008) shows that extremely dry months in Bulgaria are with relatively high frequency in the 40s and 80s of the 20th century, but after 2000 there has been an increase in occurrence of extremely wet months.

Despite the number of publications on extreme rainfall in Bulgaria, the variability in the climate system requires the updating of research with new data and methods. More regional research works are also needed. The present paper aims to present the results from the investigation of precipitation in Northeast Bulgaria in terms of the occurrence and temporal variability of extreme precipitation. The extreme high precipitation totals are analyzed by calculation of precipitation indices as number of wet days, maximum number of consecutive wet days, simple daily precipitation index, heavy and very heavy precipitation days.

STUDIED AREA, DATA AND METHODS

This present research work covers the territory of Northeastern Bulgaria. This is one of the main agricultural areas in the country for which the changes in the precipitation regime and the occurrence of extreme rainfall are of particular importance.

The analysis of extreme precipitation is based on two types of data: monthly precipitation and daily precipitation from 10 weather stations located relatively evenly in the studied area (Table 1). The period of investigation is 1992–2008. The choice of the stations and the duration of the period are determined by the availability of daily precipitation data. The source of monthly data is National Institute of Meteorology and Hydrology, Bulgaria.

The determination of months with extreme precipitation has been done against the empirical distribution of the initial data. Extreme wet months are defined as months whose monthly precipitation total is higher than 90 percentiles of empirical distribution in the period 1992–2008. The extreme precipitation are analysed on the basis of precipitation indices defined by European Climate Assessment & Dataset project (https://www.ecad.eu/, accessed by 1 April 2018). The indices are calculated on the basis of daily data as follows:

Table 1

List of meteorological stations used in the research

Meteorological station	Latitude	Longitude	Altitude /.m/
Venets	43° 33′	26° 56′	290
Vladimirovo	43° 34′	27° 32′	245
Dulovo	43° 49′	27° 8′	237
Kainardzha	43° 59′	27° 30′	173
Karapelit	43° 39′	27° 34′	227
Kubrat	43° 48′	26° 30′	201
Novi Pazar	43° 20′	27° 11′	126
Provadiya	43° 10′	27° 26′	56
Sitovo	44° 1′	27° 1′	
Tsar Kaloyan	43° 37′	26° 15′	180

1) Number of wet days – the days with R ≥ 1 mm, R – daily precipitation amount.

2) Simple daily intensity index – average precipitation amount during the wet days

$$SDII = \frac{\sum_1^w R_{wj}}{W} \text{ (mm/wet days),}$$

where: R_{wj} is precipitation amount for wet days W, where R ≥ 1 mm of the period j.

3) Maximum number of consecutive wet days – the largest number of consecutive days where R ≥ 1 mm.

4) Very heavy precipitation days – number of days where $RR_{ij} \geq 20$ mm, RR_{ij} – daily precipitation amount for the day i of period j.

RESULTS AND DISCUSSIONS

EXTREME WET MONTHS FOR THE PERIOD 1993–2008

The results from the analysis show that during the period 1993–2008 at least one extreme wet month has been observed in all of years, with the exception of 2001. The highest frequency of this indicator is for the periods 1997–1999 and 2002–2007 (Fig. 1). In 1997 and 1998 100% of the analysed stations reported an extremely wet month and 90% of the stations have extremely wet month in the years 1999 and 2004. The wettest years were 2002 and 2005, when at least one extreme wet month was observed in all 10 stations and three and more extreme wet months were observed respectively in 80% and 60% of the investigated stations (Fig. 2).

NUMBER OF WET DAYS

In general the annual number of wet days is above 60 for all of the investigated stations during the period 1993–2008. The exception is the year 2000 when this parameter varies

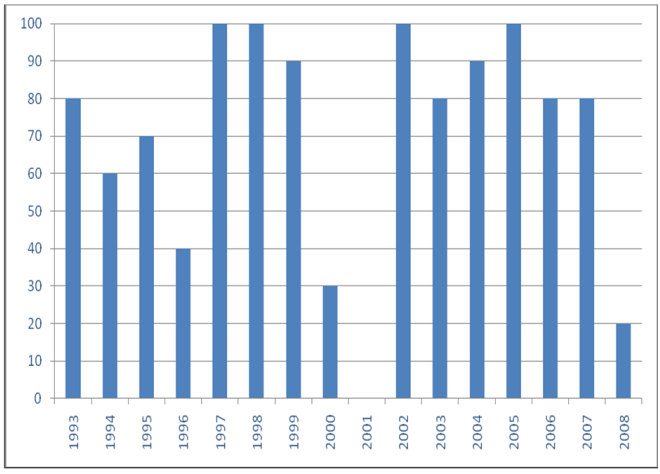

Fig. 1. Percentage of stations with at least 1 extreme precipitation month

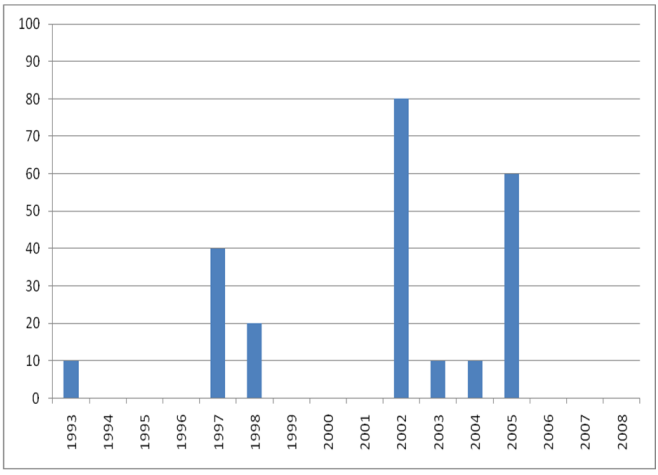

Fig. 2. Percentage of stations with 3 and more extreme precipitation months

between 45 and 63. The wettest years were 1997 with more than 80 wet days in each of the stations and 2005 when the wet days were above 90, and in 60% of the analysed stations – above 100.

The seasonal distribution of wet days shows maxima in spring for all of 10 stations (19–22 days) and minima in summer (15–18 days). The number of wet days during the winter and autumn is almost equal (17–20 days) (Table 2).

Table 2

Number of wet days during the seasons (average for the period 1993–2008)

Meteorological stations	Winter	Spring	Summer	Autumn
Venets	20	22	19	20
Vladimirovo	17	19	17	17
Dulovo	21	22	18	21
Kainardza	17	19	16	18
Karapelit	17	19	15	17
Kubrat	18	20	18	19
Novi Pazar	18	21	17	18
Provadiya	17	20	15	17
Sitovo	18	19	17	18
Tsar Kaloyan	17	21	17	19

SIMPLE DAILY INTENSITY INDEX

Simple daily intensity index (SDII) shows that for the period 1993–2008 the mean precipitation amount of the wet days in most of studied stations is highest in 2005 (between 7.7 and 11 mm) and 2002 (between 8.3 and 10 mm). The lowest values of SDII are in 2000 (between 5 and 7.6 mm) and 1996 (between 7 and 8.6 mm) (Fig. 3). The highest value of SDII in 2007 for station Tsar Kaloyan (13.3 mm) is due to the intensive rainfall in august 2007 when the area was flooded.

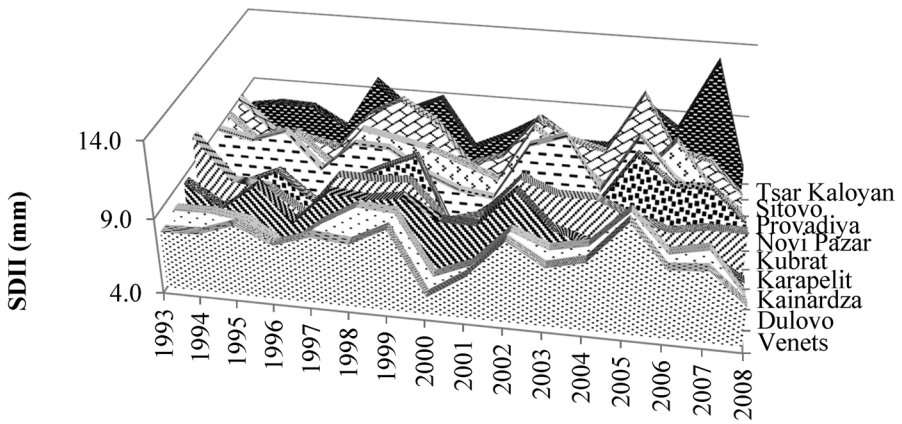

Fig. 3. Simple daily intensity index (SDII) – annual average (mm)

MAXIMUM NUMBER OF CONSECUTIVE WET DAYS

Seasonal distribution of maximum number of consecutive wet days shows the highest number in most of stations during winter and autumn. In winter during the periods 1995–1997 and 2004–2006 the maximum number of wet days is five or more in most of the investigated stations. Seven or eight consecutive wet days were observed in 40% of the stations during 1995 and in 30% of the stations during 2005. The lowest value of this index was established in 1994 (0–2), 2001 and 2002 (2–4) and 2008 (3).

During the spring maximum number of consecutive wet days is 5 or 6 in most of the studied stations for the years 1997, 2000 and 2006.

The calculations of the maximum number of consecutive wet days in the summer stand out for only one year – 1994, where the index is 5 or 6 for over 50% of the stations. During other years of the investigated period, the maximum duration of consecutive wet days is between 2 and 4.

In autumn above 5 consecutive wet days were observed almost in all of the investigated area during 1997, 2002, 2003, 2007 and 2008. The highest value of the consecutive wet days (13) is established in 2007.

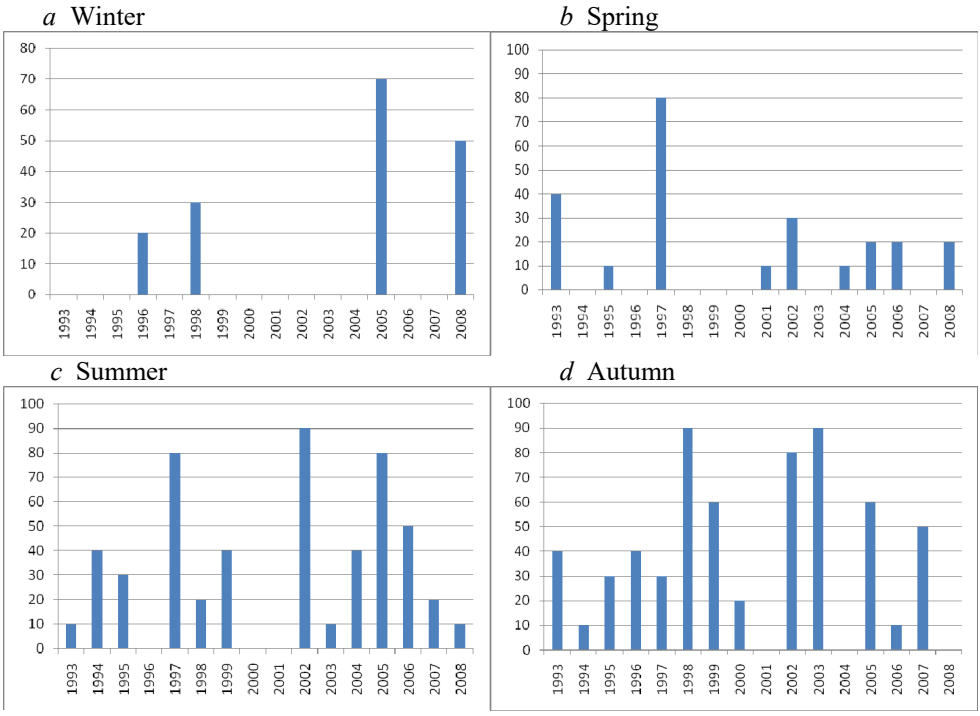

Fig. 4. Percentage of stations with 3 and more very heavy precipitation days during the seasons

VERY HEAVY PRECIPITATION DAYS

As very heavy precipitation days we consider the days with daily precipitation amount above 20 mm. The present analysis shows that very heavy precipitation days were observed most often in summer and autumn (Fig. 4).

Three and more very heavy precipitation days were established in about 80–90% of the investigated stations for summer 1997, 2002 and 2005, and for autumn 1998, 2002, and 2003.

The calculations show that the highest number of very heavy precipitation days during the years for the period 1993–2008 were observed in 2005, 2002 and 1997 (between 10 and 17) and in 1998 and 2007 (up to 11–13 days) (Fig. 5).

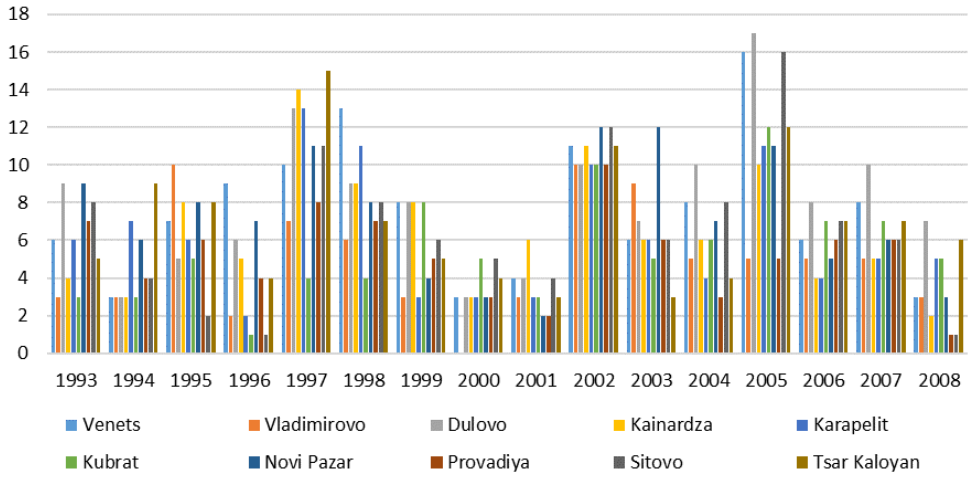

Fig. 5. Number of very heavy precipitation days

CONCLUSIONS

The paper presents the peculiarities in occurrence of extreme precipitation months and variability of precipitation indices for one of the most important agricultural area in Bulgaria – Northeastern Bulgaria. The results from the research work allow making the following conclusions:

- Since 2000 the occurrence of extremely wet months became more often but not in all of studied stations.
- The number of wet days is the highest in 2005 and 1997. According to seasonal distribution of the number of wet days the wettest season is the spring.
- Simple daily intensity index shows that for the period 1993–2008 the mean precipitation amount during wet days in most of studied stations is higher in 2005 and 2002, and reaches about 10 mm.

- In most of the cases the maximum number of consecutive wet days during the seasons is 5 or 6 but in winters and autumn this index reach 7 and 8. The increasing of maximum number of wet days since 2000 is characteristic for autumn.
- Very heavy precipitation days are observed most often in summer and autumn. The years 2005, 2002 and 1997 make impression with the highest number of very heavy precipitation days (between 10 and 17).

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