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REGIONAL CLIMATE CHANGE: PRECIPITATION VARIABILITY IN MOUNTAINOUS PART OF BULGARIA

Abstract: The aim of paper is to analyze temporal and spatial changes in monthly precipitation as well as extremely dry and wet months in mountainous part of Bulgaria. Study precipitation variability in mountainous part is very important because this part is the region where the rivers take its source from. Extreme values of monthly precipitation are important information for better understanding of the whole variability and trends in precipitation time series. The mean investigated period is 1951-2005 and the reference period is so called temporary climate - 1961-1990.

Extreme dry precipitation months are defined as a month whose monthly precipitation is lower than 10% of gamma distribution in the reference period 1961-1990. Extreme wet months are determined with respect to 90% percentiles of gamma distribution (monthly precipitation is higher than 90%).

The result of the research show that in mountainous part of Bulgaria during 1950s and 1960s number of extremely wet months is higher than number of dry months. Decreasing of monthly precipitation is a feature for 1980s. This dry period continues till 2004. The years 2000 makes impression as driest year in high mountains with about 7 extremely dry months. The second dry year is 1993. The negative precipitation anomaly is most clearly determined during last decade at study area. The present research points out that fluctuation of precipitation in mountainous part of Bulgaria are coinciding with regional and global climate trends.

Key words: monthly precipitation, seasonal precipitation, extremely dry and wet months

Introduction

Climate change is one of most significant challenges facing international community. Many research programmes at local, regional and global levels show as a main task the action to reduce, avoid, and better understand the risk associated with the climate change. Meteorological observations show that there is increasing of extremely weather events during last years. This is connected to global climate changes due to natural processes or anthropogenic changes in the composition of the atmosphere or in land use. Due to importance of the problems caused by heavy rain or drought precipitation variability in Bulgaria have been investigated by many authors (Koleva, 1995; Nikolova

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and Vassilev, 2006; Topliiski, 2002, 2005, Vekilska and Rathcev, 2000). Nonetheless the growing knowledge of climate change, many questions still seek their answers.
The proposed research is intended to provide detailed information about monthly and seasonal variation of precipitation in high mountainous part of Bulgaria. Study precipitation variability in mountainous part is very important because this part is the region where the rivers take its source from. The accent is investigation of extremely dry and wet monthly precipitation.

The tasks are:

1) Determination of precipitation anomalies;
2) Study of extremely dry and wet months – spatial and temporal changes;
3) Investigation of relationship between occurrence of extremely dry and extremely wet months and atmospheric circulation patterns.

Data

Monthly data for precipitation from 3 meteorological stations situated at high mountainous part of Bulgaria are used for achieving the aim of the research. The main investigated period is 1951-2005. The accent is the period after the year 2000. There is a missing data for station Mussala for the period 1997-1999 and for station Botev vrah for the period 1992 – 1999. Replenishment of missing values will bring more subjectivity to the investigation and because of this we did not fill the gaps. Period1961-1990 so called "contemporary climate" according the recommendation of the World Meteorological Organization (WMO) is used for reference period. Annual and seasonal precipitation total are calculated on the basis of monthly precipitation.

The data for North Atlantic Oscillation indices (NAOI) and East Atlantic pattern (EA) are used for determination the relationship between occurrence of extremely dry and extremely wet months and atmospheric circulation. The NAO refers to a north-south oscillation in atmospheric mass with centers of action near Iceland and over the subtropical Atlantic from the Azores across the Iberian Peninsula. During the months December through March the NAO accounts for more than one-third of the total variance in SLP over the North Atlantic. (Hurrell, 2000). During the positive phase of NAO negative precipitation anomalies occur over the southern Europe (Wibig, 1999).

The East Atlantic (EA) pattern is the second prominent mode of low-frequency variability over the North Atlantic, and appears as a leading mode in all months. The EA pattern is often interpreted as a "southward shifted" NAO pattern. The positive phase of the EA pattern is associated with above-average precipitation over northern Europe and Scandinavia, and with below-average precipitation across southern Europe. (Barnston, A. G., and B. E. Livezey, 1987).

Methods

Precipitation variability is presented by deviation (in %) of annual precipitation totals for every year from average annual precipitation for the period 1961-1990 (climate normal).

This indicator is calculated by dividing actual precipitation by normal precipitation which is considered to be 100%.
Rainfall Anomaly Index is used for study negative anomalies (dry events). It is calculated by

$$RAI = -3\frac{P_i - \overline{P}}{\overline{E} - \overline{P}},$$

where P_i is annual precipitation total for every year, $\overline{P}$ - average annual precipitation for period 1961-1990, and $\overline{E}$ - average of ten low precipitation totals (driest years) for the investigated period. The prefix is negative because the task is to investigate negative anomalies. If the purpose of investigation is to show duration and intensity of wet periods the prefix should be positive and $\overline{E}$ should be average of the 10 highest precipitation values on record (Hänsel, Matschullat, 2006).

Selection of months with extreme precipitation total has been made according Brazdil (2002). Extreme wet months are defined as a months whose monthly precipitation total is higher than 90% percentiles of gamma distribution in the reference period 1961-1990. As extreme dry month we consider the month with precipitation total lower than 10% of gamma distribution.

Extremely wet and dry months were determined for every of 3 investigated stations for the period 1951-2005. We consider number of station with at least one wet and one dry month during the year and number of station with three and more extremely months. This method has been applied for individual teleconnection patterns: North Atlantic Oscillation and East Atlantic. Seasonal distribution of extreme precipitation has been investigated. Seasons are determined as follow: winter – December, January, February, spring – March, April, May, summer – June, July, August, and autumn – September, October, November.

In order to estimate the relationship between occurrence of extreme events (extremely dry and extremely wet months) and atmospheric circulation patterns correlation analysis has been applied.

Results

Deviations of annual precipitation total from average of the period 1961-1990 show that the period 2000-2005 is mainly dry. In the years 2000 and 2001 annual precipitation anomalies are less than 60% of climate normal. Exceptions are the years 2005 and 2002 with precipitation anomaly above 100% of climate normal (fig. 1).

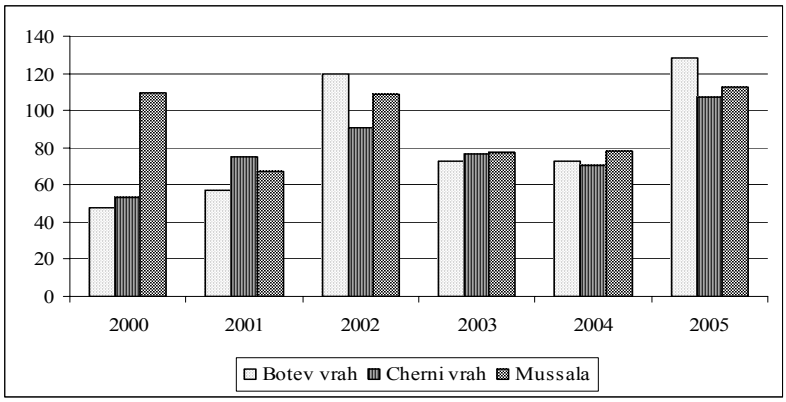

Figure 1. Annual precipitation anomalies (% of normal)

Rainfall Anomaly Index (RAI) gives us a tool to determine the duration and intensity of drought period. We have calculated RAI for station Cherni vrah which has no gaps in time series for the period 1951-2005. It is evident that the drought has been observed from 1981 to 2004 (fig. 2).

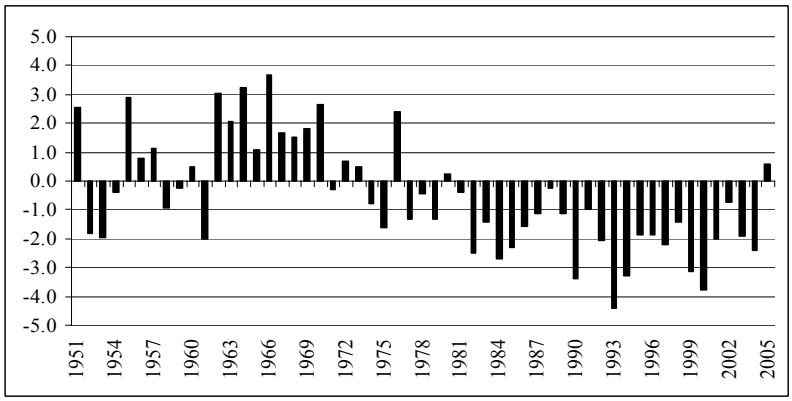

Figure 2. Rainfall Anomaly Index for station Cherni vrah

Analysis of precipitation anomaly (deviation from normal and RAI) confirms the results from previous investigation. Alexandrov (2004) point out that general trend of precipitation decreases since the beginning of the 1980s is observed for Balkan Peninsula. Precipitation changes in high mountain part of Bulgaria are coinciding with this in other parts of the country. The drought is clearly determined in 1993, 2000 and 1990. The positive precipitation anomaly has been observed form 1962 to 1970.

The drought is characteristic for the year after 1980. The years with extremely wet and extremely dry months are shown in table 1. Since 1980s occurrence of extremely dry months are more often than extremely wet months. During the last decade high precipitation has been observed in 2002 and 2005. This fact is shown by Nikolova and Vassilev (2006) for summer precipitation in Danube plain in Bulgaria. The driest years have been 2000 and 1993. The extremely wet months have been observed during 1950s and 1960s.

Table 1. Years with extreme precipitation

Stations	Number of months		
	Extremely wet		
	4	3	2
Botev vrah	1964, 1966	1954, 1962, 1963, 1965, 1991, 2002	1953, 1968, 1969, 1975, 1976, 1982, 2005
Cherni vrah	1951, 1965(5), 1970	1972	1957, 1964, 1969, 1976, 1988, 2005
Musala	1951, 1965	1956, 1964	1953, 1955, 1957, 1988
	Extremely dry		
Botev vrah	2000 (7), 1986 (4)	1962, 1965, 2001	1952, 1953, 1958, 1969, 1972, 1978, 1988, 1990
Cherni vrah	1993(5), 1997, 2000	1969, 2002,	1952, 1953, 1959, 1972, 1982, 1984, 1986-1990, 1992, 1994, 1996,
Musala	1986	1984, 1988, 2000	1960, 1965, 1968, 1985, 1992, 1993, 1996

Seasonal distribution of extremely wet and dry events show that winter in high-mountainous part of Bulgaria is wet season and summer is dry. This tendency is negative for water resources because increasing of necessity of water during summer time. Exception is station Mussala where extremely wet months are dominant during all seasons (fig. 3). We have to accept the results on figure 3. with some uncertainty because there is a gaps in time series for stations Botev vrah and Mussala. Station Cherni Vrah makes impression with very dry summer. In the period 1951-2005 nine summers at here have been with precipitation totals lower than 10 % of gamma distribution. We have to conclude that the results from precipitation variability at station Cherni vrah are more reliable because there are not gaps in time series for this station. Analysis which we have done shows negative tendency in precipitation variability at high mountainous part of Bulgaria.

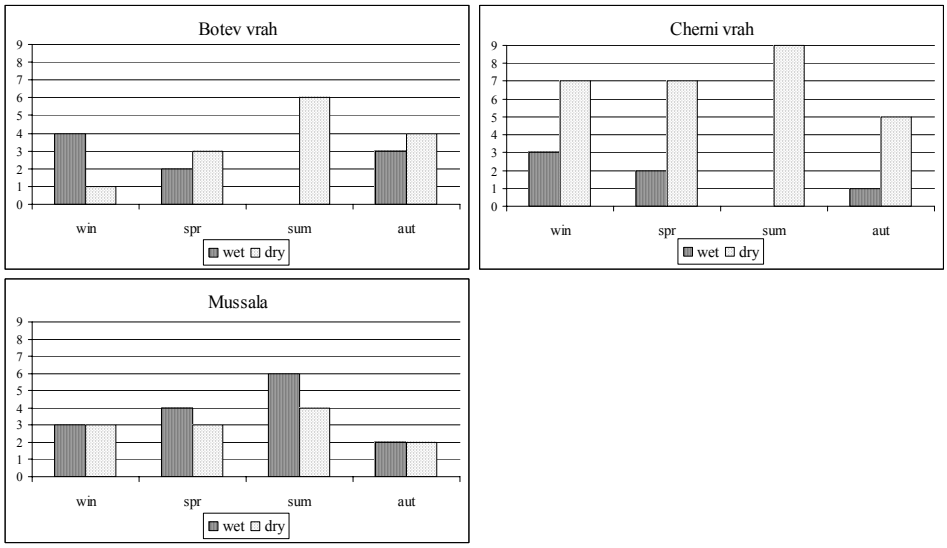

Figure 3. Number of extremely wet and extremely dry seasons

A correlation analysis has been applied in order to study impact of atmospheric circulation on occurrence of extremely wet and extremely dry months. Correlation coefficients between East Atlantic (EA) pattern and number of months with extreme high and extreme low precipitation show weak relation. The similar results have been obtained from investigation of correlation between North Atlantic Oscillation (NAO) indices and number of months with extreme high and extreme low precipitation (table 2).

Table 2. Correlation coefficients between number of months with extreme precipitation and atmospheric circulation

	Extremely dry months		Extremely wet months	
	EA	NAO	EA	NAO
Botev vrah	0.18	-0.01	-0.28	0.00
Cherni vrah	-0.25	0.20	-0.10	-0.11
Mussala	-0.28	0.20	-0.18	0.06

The results from correlation analyses are coinciding with previous research on relationship between NAO and precipitation (Nikolova, 2004). In contrast to this Ducic et all. (2007) show relatively high correlation between NAO and decadal amount of precipitation in Serbia. These allow us to conclude that precipitation variability especially for annual time series depends from many factors.

Summary

The results of present research show that during last decades precipitation variability in high mountainous part of Bulgaria follows general decreasing trend for all territory of country. The drought is very strong between 1981 and 2004. During this period occurrence of months with extremely low precipitation are more characteristic than in other years from investigated period. The years 1993, 1990 and 2000 make impression with lowest precipitation anomaly. Extremely wet months have been occurred mainly in the period 1962-1970.

According seasonal distribution of extreme precipitation summer is driest season in high part of mountains in Bulgaria. Increasing of extremely wet months has been observed in winter.

Week correlation between number of months with extreme precipitation (high or low) and atmospheric circulation patterns prove that precipitation variability is determined from many factors as well as from spatial and temporal averaged of data.

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