VARIATIONS IN PRECIPITATION IN REPUBLIC OF MACEDONIA

Mihailo Zikov
University "St's Cyril and Methodius" Faculty of Natural Sciences and Mathematics,
Institute of Geography, Republic of Macedonia
zikov@pmf.ukim.mk

Verica Bakeva
University "St's Cyril and Methodius"
Faculty of Computer Science and Engineering, Republic of Macedonia
verica.bakeva@finki.ukim.mk

One of the most important meteorological element in modern climatology is the study of the regime of the multiyear changes in precipitation. Therefore, in this paper, we analyze the variations in precipitation in the Republic of Macedonia. We consider the measuring points Skopje, Stip, Demir Kapija and Prilep in the period from 1925 to 2003. Using several mathematical-statistical and analytical methods we make attempt to discover the characteristics of the structure of the multiyear variations in precipitation as the distribution of precipitation from year to year, linear trend, the extreme phenomena, the existence of cycles, e.t.c. The obtained results provide an answer to many issues related to the considered subject.

Key words: *Rain-sum, variations, regression line, time-series analysis*

INTRODUCTION

This processing and analysis is based on the average values of the annual quantities of precipitation (rain-sums) in Republic of Macedonia. A database has been created for four meteorological measuring stations: Skopje, Stip, Demir Kapija and Prilep for a period of 78 consecutive years, from 1925 to 2003. The exception is only Demir Kapija, where we have data for the period from 1933 to 2003. For their analysis we use the following methods: linear regression and time-series analysis. They enable to perceive variations of precipitation in the indicated multiyear time period, as a significant characteristic of the space. Variations in the precipitation are mainly conditioned by the relief, the character of the base, air masses, cloudiness, and the spatial situation in Republic of Macedonia. Namely, Republic of Macedonia is in southern part of Europe and in the center of the Balkan Peninsula. There is a variable relief physiognomy since about 25% of the relief is flat, and about 75% is hilly-mountainous, of which 9.3% is highly mountainous and has great vertical relief division (the lowest point is on 44 m.a.s.l. and the highest point is on 2764 m.a.s.l). The aforementioned

factors have great impact on the average annual amount of precipitation and on their spatial and temporal distribution. Most precipitation throughout the year in our country falls in the river basin of River Radika, more than 1.400 mm, and the least precipitation is in the middle Povardarie and the field Radovisko Pole, from 440 to 492 mm/year. From here to all directions, precipitation increases from 504 to 560 mm in the high valleys and in the valley of Gevgelija-Valandovo it reaches about 600 to 630 mm, while on the mountains its annual quantity is between 800 to 1400 mm or more. These amounts of precipitation show large variations in the analyzed period from 1925 to 2003 as annual or periodic amounts. The analysis that follows provides an opportunity to discover the structure of the multiyear changes in precipitation and to prove whether precipitation decreased or increased there are increasingly more observations that in some places the dry and hot summers climate turns into rainy and cold summers, and the rainy regions get increasingly less than the expected precipitation.

RESEARCH METHODS

A statistical calculation of the data is done by using statistical package and involves the following analyses:

- *Regression line*. In order to check if a linear trend exits, we find a regression line of the annual rain-sum for the whole period 1925-2003. The regression lines are obtained using the least squares method.
- *A time-series analyses.* We use the method of moving averages in order to eliminate random oscillations and to notice some regularities. For observed period from 1925 to 2003, the data form a time series of 79 years. A chronological diagram is prepared for the measured values and moving averages. We determine the moving averages for 5 years since with this arrangement we obtain the more regular line. From this line we can see more clearly the tendency or the change in the step of the average annual sums.

Statistical analyses and discussion

Using the statistical methods mentioned above we make several analyses of the data for rain-sum in four regions: Demir Kapija, Shtip, Prilep and Skopje. First, we find the linear trend (regression line) of rain-sum during the whole period from 1925 to 2011 (Figure 1).

Moving averages. In Figure 2, we present the results obtained by a moving average method. In order to eliminate the random oscillation, we find the moving average for $N = 5$ years (read line). Real (measured) annual rain-sum are presented by a blue line, and average annual rain-sum for the whole period – by the green line.

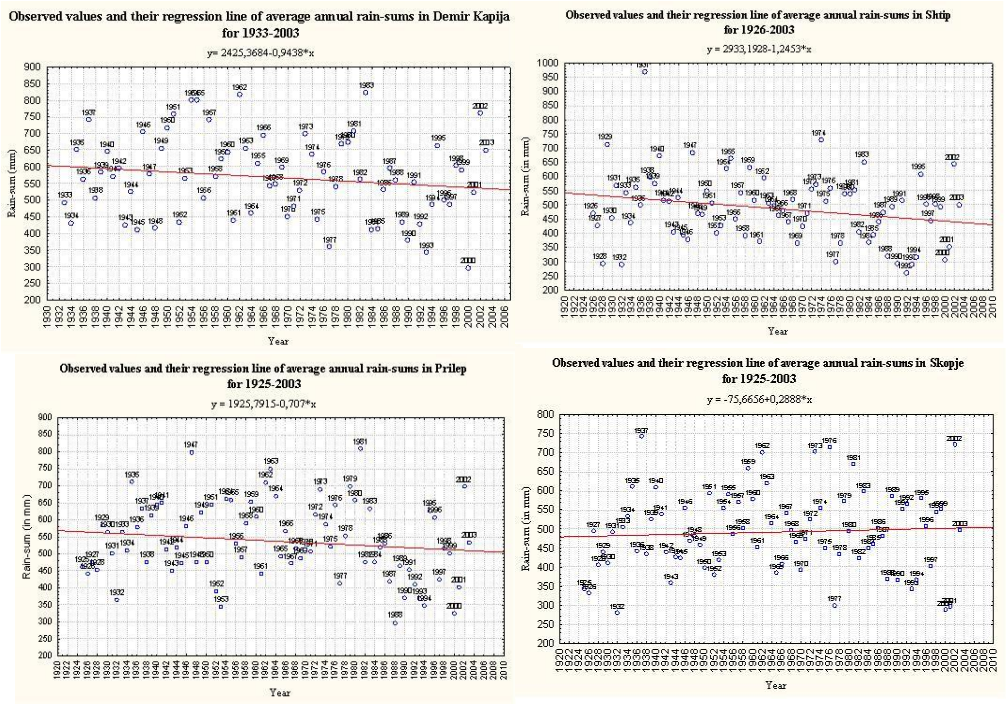
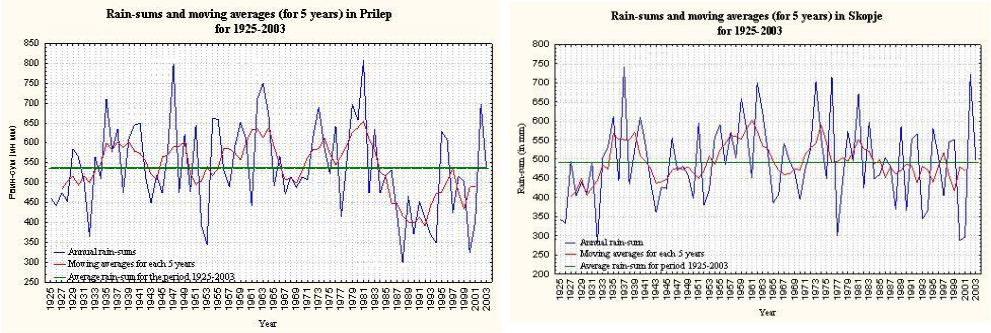


Figure 1. We can see that the linear trend is slightly decreasing in Demir Kapija, Shtip and Prilep and it is slightly increasing in Skopje. In all cases we have a large deviation of the data from the regression line.



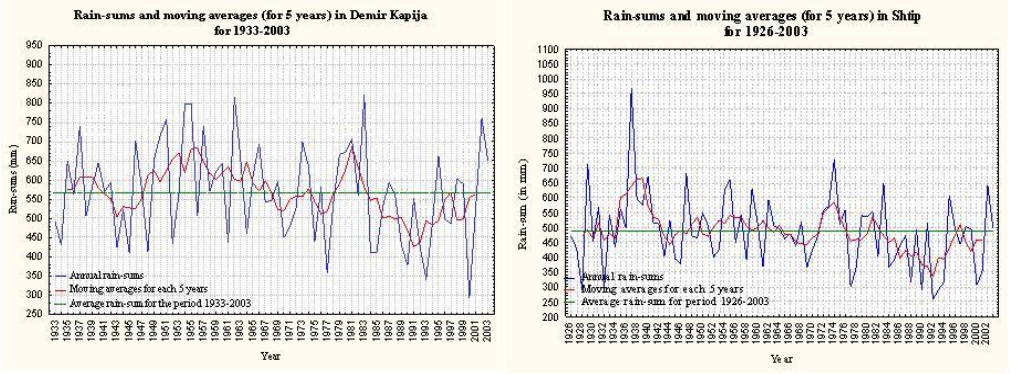


Figure 2 If we analyze the red line in each plot, we cannot find some regularity (periodicity), but we can find periods with a small amount of precipitation (dry periods with rain-sums under the average) and periods with a large amount of precipitation (wet periods with rain-sums above the average). If we consider the amplitudes of rain-sums, the driest noticed period is the period for 1984-2001, especially in Demir Kapija, Ship and Prilep. The same period is also dry in Skopje, but the amplitudes of rain-sums are smaller.

Table 1. Average rain-sums (in mm) in considered intervals

m.m./period	1925-1933	1934-1941	1942-1953	1954-1963	1964-1972	1973-1982	1983-2001	Average*
Prilep	**492**	**615**	**523**	**615**	**521**	**619**	**458**	**549**
Stip	**465**	**626**	**475**	**528**	**466**	**518**	**420**	**500**
D.Kapija	**-**	**577**	**561**	**659**	**545**	**607**	**488**	**573**
Skopje	**400**	**549**	**450**	**572**	**460**	**542**	**461**	**490**

** Average amount of precipitation for the period from 1925 to 2001*

*** The average amount of precipitation for the following periods: Prilep (1925-1934, 1935-1941, 1942-1953, 1954-1964, 1965-1972, 1973-1981, 1981-2001) Stip (1925-1934, 1935-1941, 1942 -1953, 1954-1963, 1964-1972, 1973-1981, 1981-2001) Demir Kapija (1933-1942, 1943-1953, 1954-1963, 1964-1972, 1973-1983, 1984-2001) Skopje (1925- 1932, 1933-1941, 1942-1953, 1954-1963, 1964-1972, 1972-1981, 1982-2001).*

The first period was with duration of 8-10 years, the second of 7-10 years, the third of 11-12 years, the fourth of 10-11, the fifth of 7-9 years, the sixth of 9-11 years, and the seventh of 18-20 years. All periods according to the average amount of precipitation deviate in relation to the average amount of precipitation for the period from 1925 to 2001.

Tabele. 2. Deviation of the average periodic amount of precipitation in mm from the average for the period from 1925 (6) – 2001.

m.m./period	1925-1933	1934-1941	1942-1953	1954-1963	1964-1972	1973-1982	1983-2001	Average*
Prilep	**-57**	**+66**	**-26**	**+66**	**-28**	**+70**	**-91**	**549**
Stip	**-34**	**+127**	**-24**	**+29**	**-33**	**+19**	**-79**	**500**
D.Kapija	**-**	**+4**	**+12**	**+86**	**-28**	**+24**	**-119**	**573**
Skopje	**-90**	**+59**	**-40**	**+82**	**-30**	**+52**	**-29**	**490**

** average amount of precipitation for the period 1925-2001*

Hence, in Republic of Macedonia, during the 20th century there are periods with increased amounts of precipitation (very humid or strongly humid periods) and periods with reduced amounts of precipitation (dry periods). The deviations are in positive or negative

direction. The drier periods are below the average annual amounts of precipitation from 1925 to 2001 and last from 1925 to 1934, 1942 to 1953, 1964 to 1972 and 1982 to 2001. The longest dry period started in 1982 and lasted until 2001 (of 18 to 20 years) and in Skopje, it was from 1984 to 2003, although the driest period is from 1925 to 1933, and the driest years in order are 1932, 1978, 2000, 2001.

From the very humid periods, according to the development tendency of precipitation, we can indicate the periods from 1933 to 1942, from 1954 to 1963 and from 1973 to 1982, which periods have values of the average annual amounts of precipitation above the average value for the observed period from 1925 to 2001 year. According to the length of duration of the very humid (transgressive) and slightly humid (regressive) periods, the measuring points can be separated into two groups: The first group includes Prilep, Stip and Demir Kapija that have the same characteristics, and Skopje is in the second group with different amplitudes and duration of periods.

CONCLUSION

In this paper, we analyze the variations in precipitation in Republic of Macedonia refers to the measuring meteorological stations: Skopje, Stip, Prilep and Demir Kapija, for the period 1925-2003, and we try to find the characteristics in the structure of the multiyear variations in precipitation, extreme periods, the existence of cycles etc., since they show that there is climate change as part of the great challenge of sustainable development.
The conducted research shows that:

- The average annual amount of precipitation in the observed period from 1925 to 2003 tends to decline slightly, while in all measuring points there are similar or same more humid periods (from 1933 to 1942, 1954 to 1963 and 1973 to 1982) or drier periods (from 1925 to 1934, 1942 to 1953, 1964 to 1972 and 1982 to 2001). In all graphs the deviation of data is quite large.
- In all measuring points, one can notice from the lines of moving averages that there is no rule, i.e., there are no clearly expressed periods and for this reason we can consider time series as random, although at first glance they show the occurrence of a alternating change of more humid and drier periods.
- In the 20^{th} century in our country, the driest and the longest period is from 1982 to 2001.
- The amplitudes and the duration of periods have different values.

The obtained results of the research about the variations of precipitation clearly show that new implications on human activities are possible, and the most vulnerable are certainly the activities in the sector of agriculture.

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Authors

Mihailo Zikov

Doctor of geographical sciences, fulltime professor at the Institute of Geography, Faculty of Natural Sciences and Mathematics at the University of "St's Cyril and Methodius", in Skopje, Republic of Macedonia. Scientific area of research includes: phusical geography (Climatology) and Spatial Planning. Publications: 7 books and textbooks and 32 published research papers. Has participated in a great number (40) of congress, scientific symposiums and International Scientific conferences. Took part in the preparation of several scientific and aplicative projects and was the leader and main researcher in 3 projects. Member of more than 15 academic and social institucions.

Verica Bakeva

Doctor in computer sciences, full professor at the Faculty of Computer Science and Engineering at the University of "Ss Cyril and Methodius", in Skopje, Republic of Macedonia. Scientific area of research includes: probabilistic models and applications. Publications: 32 published research papers, 1 university textbook and co-author of several textbooks of mathematics in secondary schools. Main researcher in 2 scientific projects and participant in several scientific and applicative projects.