ANALYSIS OF PRECIPITATION ANOMALIES IN TIMISOARA USING THE METHOD OF STANDARDIZED PRECIPITATION ANOMALY

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Abstract

The present paper analyzes the annual and monthly precipitation amounts from Timisoara weather station, during 1961-2011, using the method of Standardized Precipitation Anomaly (SPA). The purpose of this paper was to identify the monthly and annual positive and negative precipitation anomalies, mainly to identify the climatic hazards generated by the excess and deficit of precipitation. In this regard, the positive and negative pluviometric extremes were chosen, using the percentile method. Extremely wet/dry years and months have been highlighted, as well as the polynomial and linear tendencies of the annual and monthly SPA values. The result was that in the Timisului Plain, the hazards generated by pluviometric excess can produce starting from annual SPA values higher than +1.7 and annual precipitation amounts over 790 mm. Hazards generated by pluviometric deficit may occur from annual SPA values lower than -1.4 and annual precipitation amounts of less than 440 mm. The linear tendency of the annual SPA values is of slight growth. The analysis of the monthly SPA values shows that the hazards generated by pluviometric excess are much more intense than those generated by pluviometric deficit. The spring, the beginning and end of summer and the autumn months became wetter in recent years, while the winter and mid-summer months became drier.

Key words: standardized precipitation anomaly, climatic hazard, pluviometric excess, pluviometric deficit, tendency.

INTRODUCTION

Banatului Plain – where Timisoara weather station is located – is characterized by the increasingly higher frequency and intensity of meteorological hazards, especially in recent years. The cause lies in its geographical position, as the plain territory is crossed easily by air masses of Atlantic or Mediterranean origin. The latter carry along a hot and humid air, generating large amounts of precipitation in short periods of time. In contrast, invasions of tropical air masses, very hot and dry, produce extreme and lasting drought episodes. As a result, excess rainfall and drought are common here, which is why this research topic has been chosen. These hazards generate serious damage in the area, which is agricultural by excellence (Bogdan, Niculescu, 1999; The Climate of Romania, 2008).

The subdivision of Banatului Plain, where Timisoara weather station is located, is Timisului Plain (Posea, 1997). In Timisoara, the multi-annual average amount of precipitation stands at 599.6 mm (period 1961-2011).

MATERIAL AND METHODS

The present paper analyzes the annual and monthly precipitation amounts from Timisoara weather station, during 1961-2011, using the *method of Standardized Precipitation Anomaly (SPA)*. The data were provided by the archives of the National Meteorological Administration. The purpose of this paper is to identify the monthly and annual positive and negative precipitation anomalies, mainly to identify the climatic hazards generated by the excess and deficit of precipitation. Thus, the paper highlights the positive and negative pluviometric extremes, representing deviations from the multi-annual average precipitation values.

The monthly standardized precipitation anomalies have been calculated according to the equation (Busuioc, 1992):

$$SPA = (x - \bar{x}) / \sigma \qquad \sigma = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1}}$$

where:

$\bar{x}$ - the multi-annual average monthly amount of precipitation;

x - the precipitation amount of a particular month;

σ - the standard deviation (average quadratic deviation) of the monthly amount of precipitation;

n - the length of the data row.

The analysis of precipitation using the SPA method is very common in the specialized literature, the authors attributing the months/years various pluviometric ratings, from "exceptionally dry" to "exceptionally wet". The thresholds between the chosen value classes differ, however, from one author to another (Kutiel, Paz, 1998, Maheras et al., 1999, Păltineanu et al., 2000, Dumitraşcu et al., 2002, all of them quoted by Cheval et al., 2003). Therefore, for better emphasizing the hazards generated by precipitation, *the percentile method* has been used to establish thresholds between the pluviometric ratings, a method considered more efficient (Busuioc, personal communication; Şerban, 2005; Şerban et al., 2008; Şerban, 2010). The method relies on the increasing ordering of the n values of a data row and dividing them into k equal parts (n/k) (Ţarcă, 1998, quoted by Cheval et al., 2003).

According to the percentile method, 10 classes of values were established for annual and monthly SPA. The SPA values of the 90-100% class represented hazards generated by pluviometric excess ("extremely rainy" months and years) and the values of the 0-10% class, hazards generated by pluviometric deficit ("extremely dry" months and years).

RESULTS AND DISCUSSION

Annual pluviometric anomalies

Based on the percentile method, classes of values and pluviometric ratings were established for the years between 1961 and 2011, at Timisoara weather station (Table 1).

Table 1

The wet, normal and dry years recorded at Timisoara weather station (1961-2011)

STATION/ YEARS	Extremely wet	Very wet	Wet	Moderately wet	Normal
Timisoara	**1970**	1999	1981	2007	1989
	1969	1974	1991	1979	1966
	1996, 2005	1995	1982	1963	1964
	2010	2004	1997	1975	1980
		2001	1977	2009	1978
STATION/ YEARS	**Extremely dry**	**Very dry**	**Dry**	**Moderately dry**	1972
Timisoara	**2000**	1993	1984	1973	1987
	2011	1992	1990	1998	2008
	1983	1994	1985	1968	2006
	1961	1962	1988	1965	2003
	1971	1967	1976	1986	2002

The positive precipitation anomalies of over 90% are between +1.7 and +2.1, and the negative ones, below 10%, are between -1.4 and -2.6 (Table 2). It is noted thus, that the annual negative anomalies vary more than the positive ones. Also, negative anomalies reached higher values than positive anomalies, meaning that the precipitation deficit of the years 2000 and 2011 was more intense in Timisoara, than the precipitation excess of 1970 and 1969.

Table 2

The extremely wet/dry years, the SPA values and annual precipitation amounts corresponding to those years, at Timisoara weather station (1961-2011)

YEARS	Year	SPA value	Precipitation (mm)
Extremely wet	**1970**	+2,13	844,0
	1969	+1,78	804,7
	1996, 2005	+1,67	791,3
	2010	+1,66	790,3
YEARS	**Year**	**SPA value**	**Precipitation (mm)**
Extremely dry	**2000**	-2,64	296,3
	2011	-1,82	389,8
	1983	-1,67	407,2
	1961	-1,48	429,9
	1971	-1,40	438,5

The wettest year during 1961-2011 was ***1970,*** and the driest ***2000.*** In 1970 there were catastrophic floods across the whole country, especially in Transylvania. This year was preceded in Timisoara, by another extremely wet year, 1969. Both years recorded over 800 mm precipitation. After two years with particularly abundant rainfall, an extremely dry year, 1971, followed. The year 2000 was an extremely dry year across the country, in Timisoara the drought intensity pointing out the very low value of the SPA (-2.6), and also the annual precipitation amount (below 300 mm).

It is noted that, *in general, extremely dry years have occurred at intervals of about 10 years, which coincides with the solar activity cycle*. Also, the extremely dry year 2011 was preceded by an extremely wet one (2010). The year 2000 was preceded by a very wet year, 1999, when over 770 mm annual precipitation was recorded (+1.5 SPA value). In fact, the entire interval 1995-1999 – which preceded the great drought of 2000 – was rainy. It is also noted that if the wettest years (1969 and 1970) were produced at the beginning of the analyzed period, the driest years (2000 and 2011) were produced at its end.

Table 2 shows the SPA values and the annual amounts of precipitation starting from that the pluviometric hazards are reported in Timisoara. Thus, *in the Timisului Plain, the hazards generated by pluviometric excess can produce starting from annual SPA values higher than +1.7. These values correspond to annual precipitation amounts over 790 mm. Hazards generated by pluviometric deficit may occur from annual SPA values lower than -1.4. They correspond to annual precipitation amounts of less than 440 mm.*

Figure 1 shows the years with positive and negative precipitation anomalies, and also periods of consecutive surplus years or those of consecutive deficient years.

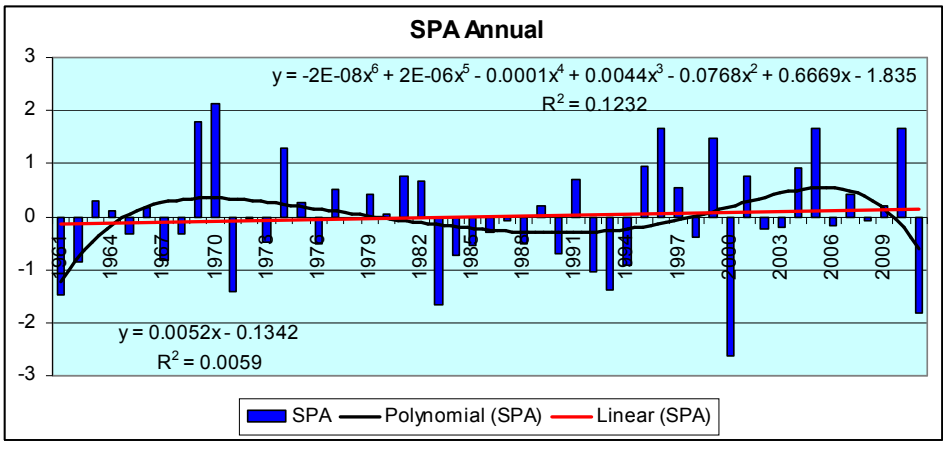

Fig. 1. The linear and polynomial tendency of the annual SPA values, at Timisoara weather station (1961-2011)

The longest period of deficient consecutive years is of 6 years (1983-1988). It is longer than the maximum period of consecutive surplus years (1979-1982, 4 years). The periods of consecutive surplus years have a slightly higher frequency (7 periods) as compared to the deficient ones (6 periods). However, the number of years with high SPA values, over +1 equals the number of years with SPA values below -1 (7 years each). This suggests that, in general, the intensity of rainy periods is equal to the intensity of dry periods in Timisoara.

The polynomial tendency of the annual SPA values (Fig. 1) shows that, after the drought of the years 1961-1962, a long period of precipitation surplus (1963-1982) followed, then one of precipitation deficit (1983-1994). A rainy period (1995-1999) follows, then the great drought of 2000, then another rainy period (2001-2010), after which the analyzed period ends with another great drought, the year 2011. Generally, we notice the period 1983-1994, with a large number of years with pluviometric deficit, and also the period 1995-2010, with a large number of excess years. To highlight the polynomial tendency, the polynome of 6^{th} order was used.

The linear tendency of the annual SPA values (Fig. 1) for the period 1961-2011, was of *slight growth.* The growth was given by the fact that the last years of the analyzed period were years with pluviometric excess.

Monthly pluviometric anomalies

The analysis of the monthly SPA values revealed the extreme months – in terms of rainfall – which occurred in Timisoara, thus the hazards generated by the pluviometric excess and deficit (Table 3).

The extremely rainy months had SPA values between +1.13 and +4.11. However, for the wettest month of the data row, the positive anomalies rose to SPA values between +2.30 (January 1963) and +4.11 (April 2005). Thus, the wettest months were: *April 2005* (+4.11 SPA and 154.4 mm rainfall); *October 1974* (+3.99 SPA and 194.7 mm); *July 1999* (+3.47 SPA and 187.1 mm); *September 2001* (+3.34 SPA and 146.6 mm); *May 1970* (+3.10 SPA and 166.2 mm) etc.

The extremely dry months had SPA values between -0.99 and -1.80. But for the driest month of the data row, the negative anomalies lowered to SPA values between -1.13 (October 1965) and -1.80 (April 2007), most values ranging between -1.5 and -1.7. The driest months were as follows: *April 2007* (-1.80 SPA and 4.4 mm precipitation); *November 2011* (-1.73 SPA and 0.2 mm); *March 1961* (-1.69 SPA and 2.4 mm); *December 1972* (-1.68 SPA and 0.6 mm) etc.

All the above shows that, in Timisoara, both the rainiest month of the interval 1961-2011 and driest occurred in April, and also that, these months were recorded by the end of the analyzed period. Hazards due to

pluviometric excess can occur *in any month of the year*, with greater intensity in April-May, July, September-October. Hazards due to pluviometric deficit may also occur in any month of the year, with the highest intensity in March-April and November-December. Also, *positive monthly pluviometric anomalies are much higher, in terms of value, than the negative ones.* Therefore, we can say that at the weather station Timisoara, *the hazards generated by pluviometric excess are much more intense than those generated by pluviometric deficit*. This is due to the Mediterranean influences of the region's climate.

Table 3

The wettest and driest months recorded at Timisoara weather station (1961-2011)

MONTHS	Jan.	Febr.	March	April	May	June
Extremely wet	**1963**	**1969**	**1962**	**2005**	**1970**	**1969**
	1987	1978	1988	1989	1987	2008
	1984	2007	1981	1997	1996	1995
	1979	1999	1987	2001	1974	1992
	2003	1970	1970	2006	2010	2010
	July	**August**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
	1999	**1989**	**2001**	**1974**	**2004**	**1969**
	1982	**2005**	1996	1972	2009	1981
	1997	1975	1995	2003	1980	1999
	1986	1994	1978	1992	1962	1963
	2011	2002	1976	1997	1985	2005
MONTHS	**Jan.**	**Febr.**	**March**	**April**	**May**	**June**
Extremely dry	**1989**	**1998**	**1961**	**2007**	**1962**	**1968**
	1990	1976	1998	1968	1993	1972
	1964	1987	1992	1984	1977	2011
	1961	1975	1972	2011	1994	1962
	1973	2000	2002	1996	1992	2004
	July	**August**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
	1985	**1992**	**1961**	**1965**	**2011**	**1972**
	1989	2011	2009	1962	1986	1975
	1988	2003	1986	2000	1982	1971
	1992	2000	1969	1995	1978	2001
	2010	1982	1982	1978	1994	1998

Table 4 shows the SPA values and monthly precipitation amounts starting from that the pluviometric hazards are reported in Timisoara, for each month of the year. Thus, in the Timisului Plain, *the hazards generated by pluviometric excess can produce starting from monthly SPA values higher than +1.1 to +1.7 and monthly precipitation amounts over 60-130 mm. Hazards generated by pluviometric deficit can occur from monthly SPA values lower than -1.0 to -1.4 and monthly precipitation amounts of less than 5-35 mm.*

Table 4

The SPA values and monthly precipitation amounts starting from that the pluviometric hazards are reported at Timisoara weather station (1961-2011)

MONTHS		Jan.	Febr.	March	April	May	June
Extremely wet	*SPA*	+1,37	+1,64	+1,42	+1,13	+1,68	+1,48
	Precip.	69,0	77,9	62,3	78,8	118,0	131,3
		July	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
	SPA	+1,29	+1,25	+1,32	+1,48	+1,50	+1,26
	Precip.	107,9	98,6	85,6	99,4	91,1	88,2
MONTHS		**Jan.**	**Febr.**	**March**	**April**	**May**	**June**
Extremely dry	*SPA*	-1,27	-1,02	-1,42	-1,11	-1,07	-1,24
	Precip.	7,5	8,5	7,6	22,0	24,6	34,8
		July	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
	SPA	-0,99	-1,21	-1,18	-1,01	-1,21	-1,20
	Precip.	25,0	9,4	10,1	4,7	14,9	14,8

The linear tendency of the monthly SPA values shows that, between 1961 and 2011, they have been increasing in many months. For *March, April, June, August, September* and *October* it shows an *increasing* tendency. For *January, May, July* and *December* it shows *downward* tendency, and *February* and *November* have a *constant* trend. The highest growth was in September and August, and the greatest decrease in July (Fig. 2-5).

Therefore, we conclude that in Timisoara, *the spring, the beginning and end of summer and the autumn months became wetter in recent years,* while *the winter and mid-summer months became drier*.

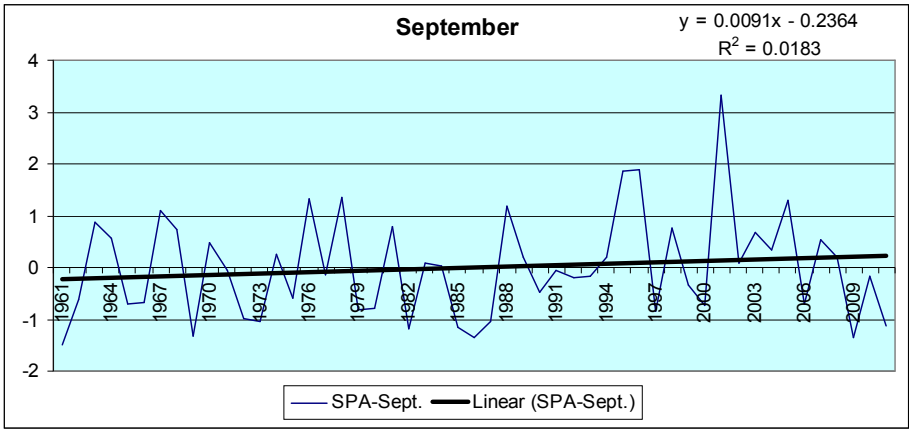

Fig. 2. The linear tendency of the SPA values of September, at Timisoara weather station (1961-2011)

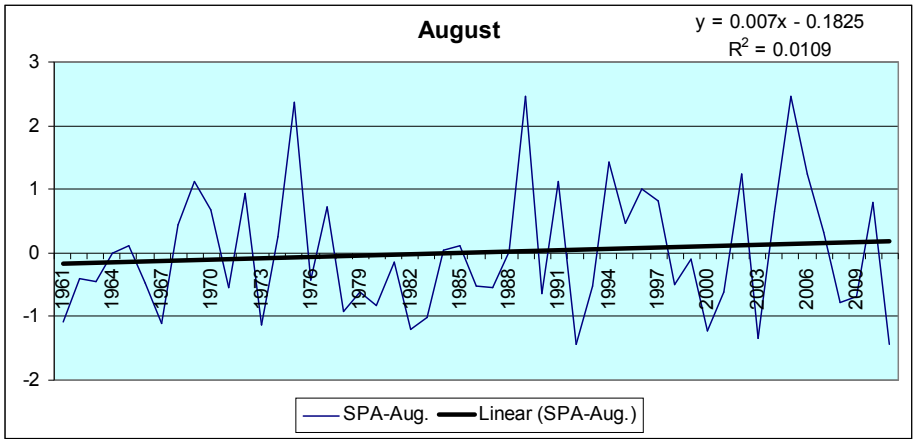

Fig. 3. The linear tendency of the SPA values of August, at Timisoara weather station (1961-2011)

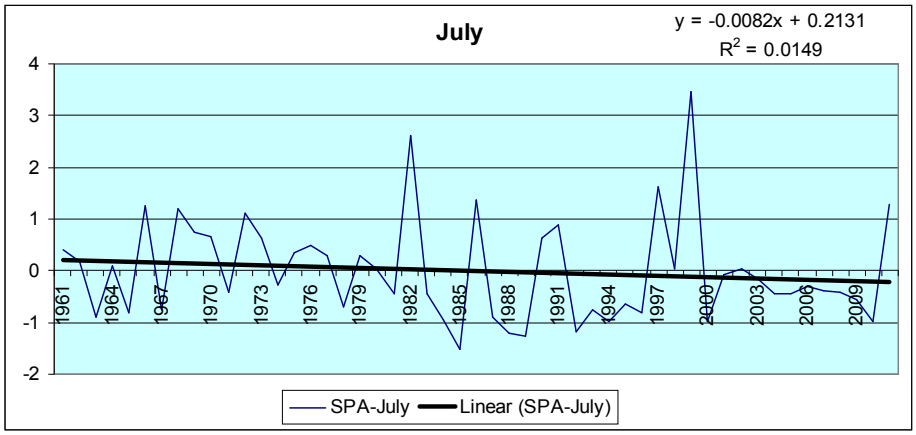

Fig. 4. The linear tendency of the SPA values of July, at Timisoara weather station (1961-2011)

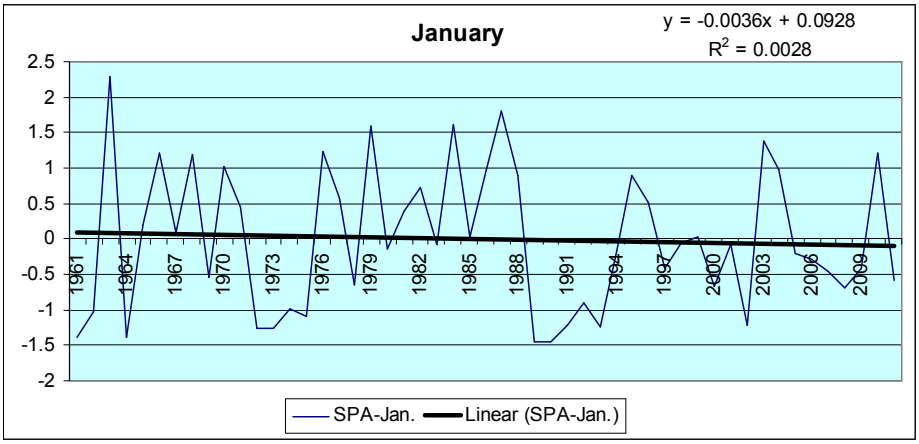

Fig. 5. The linear tendency of the SPA values of January, at Timisoara weather station (1961-2011)

The decrease of the winter precipitation amounts in recent years, in Romania, but in southern Europe and the Mediterranean basin as well, has been noticed by many authors, who found strong positive anomalies of air pressure and negative anomalies of precipitation over these regions, in this season (Busuioc, von Storch, 1996; Maheras, 2000; Hurrell, 1995, quoted by Boroneanț, Rîmbu, 2003; Palutikof, 2003; Luterbacher, Xoplaki, 2003; Maheras, Anagnostopoulou, 2003; Türkeş, 2003 etc.).

CONCLUSIONS

The paper highlights the climatic hazards generated by the excess and deficit of precipitation. In the Timisului Plain, the hazards generated by pluviometric excess can produce starting from annual SPA values higher than +1.7 and annual precipitation amounts over 790 mm. Hazards generated by pluviometric deficit may occur from annual SPA values lower than -1.4 and annual precipitation amounts of less than 440 mm. The wettest year during 1961-2011 was 1970, and the driest 2000. The linear tendency of the annual SPA values was of slight growth.

The analysis of the monthly SPA values shows that the hazards generated by pluviometric excess are much more intense than those generated by pluviometric deficit. In the Timisului Plain, the hazards generated by pluviometric excess can produce starting from monthly SPA values higher than +1.1 to +1.7 and monthly precipitation amounts over 60-130 mm. Hazards generated by pluviometric deficit can occur from monthly SPA values lower than -1.0 to -1.4 and monthly precipitation amounts of less than 5-35 mm. The spring, the beginning and end of summer and the autumn months became wetter in recent years, while the winter and mid-summer months became drier.

REFERENCES

1. Bogdan Octavia, Niculescu Elena, 1999, *Riscurile climatice din România*, Edit. Sega-Internațional, Bucureşti, 280 p.
2. Boroneaț Constanța, Rîmbu N., 2003, *Moduri ale variabilității deceniale a precipitațiilor din timpul iernii în regiunea atlantico-europeană şi legătura acestora cu anomaliile circulației atmosferice şi a temperaturii suprafeței mării*, Analele Univ. Ovidius, Seria Geografie, vol.1, Ovidius University Press, Constanța, pp. 32-42
3. Busuioc Aristița, 1992, *Synthetic description method for regional climate anomalies*, Meteorologia şi Hidrologia, INMH, vol.22, 2, Bucureşti, pp. 23-27
4. Busuioc Aristița, von Storch H., 1996, *Changes in the winter precipitation in Romania and its relation to the large-scale circulation*, Tellus, 48 A, 4, Munksgaard, UK, pp. 538-552

5. Cheval S., Croitoru Adina, Dragne Dana, Dragotă Carmen Sofia, Gaceu O., Patriche C.V., Popa I., Teodoreanu Elena, Voiculescu M., 2003, *Indici şi metode cantitative utilizate în climatologie*, Edit. Univ. din Oradea, Oradea, 119 p.
6. Dragotă Carmen Sofia, 2006, *Precipitaţiile excedentare în România*, Edit. Academiei Române, Bucureşti, 175 p.
7. Ion-Bordei Ecaterina, 2009, *Rolul lanţului alpino-carpatic în evoluţia ciclonilor mediteraneeni*, Edit. Printech, Bucureşti, 138 p.
8. Josan N., Sabău N.C., Romocea Tamara, Costea Monica, Cristea Maria, Borota D., Berchez O., Ilieş Dorina, Nistor S., Vlaicu M., 1999, *Hazarde şi riscurile naturale şi antropice în bazinul Barcăului*, Edit. Univ. din Oradea, Oradea, 156 p.
9. Luterbacher J., Xoplaki E., 2003, *500-year Winter Temperature and Precipitation Variability over the Mediterranean Area and its Connection to the Large-scale Atmospheric Circulation*, in Mediterranean Climate – Variability and Trends, Springer-Verlag Berlin Heidelberg, Germany, pp. 133-151
10. Maheras P., 2000, *Synoptic situations causing drought in the Mediterranean Basin*, in Drought and Drought Mitigation in Europe, Kluwer Academic Publishers, Dordrecht, The Netherlands, pp. 91-102
11. Maheras P., Anagnostopoulou Christina, 2003, *Circulation Types and Their Influence on the Interannual Variability and Precipitation Changes in Greece*, in Mediterranean Climate – Variability and Trends, Springer-Verlag Berlin Heidelberg, Germany, pp. 215-239
12. Palutikof J., 2003, *Analysis of Mediterranean Climate Data: Measured and Modelled*, in Mediterranean Climate – Variability and Trends, Springer-Verlag Berlin Heidelberg, Germany, pp. 125-132
13. Posea Gr., 1997, *Câmpia de Vest a României*, Edit. Fundaţiei "România de Mâine", Bucureşti, 429 p.
14. Romocea Tamara, Pantea Emilia, 2010, *Karst aquifers as a source of water. Case study: Bratca area*, Analele Universităţii din Oradea, Fasc. Protecţia Mediului, vol. XV, anul 15, Edit. Univ. din Oradea, Oradea, pp. 802-807
15. Şerban Eugenia, 2005, *Some aspects regarding the analysis of precipitation anomalies in the West Plain – situated at the North of the Mures River*, Analele Universităţii „Ovidius", Seria Geografie, vol.2, Ovidius University Press, Constanţa, pp. 75-83
16. Şerban Eugenia, 2010, *Hazarde climatice generate de precipitaţii în Câmpia de Vest situată la nord de Mureş*, Edit. Universităţii din Oradea, Oradea, 395 p.
17. Şerban Eugenia, Santaguida R., Lauria L., 2008, *Anomalies des précipitations à la station météorologique de Monte Cimone, Italie*, XXI^{ème} Colloque de L'Association Internationale de Climatologie „Climat et risques climatiques en Méditerranée", Actes du colloque, 9-13 septembre 2008, Montpellier, France, pp. 581-586
18. Türkeş M., 2003, *Spatial and Temporal Variations in Precipitation and Aridity Index Series of Turkey*, in Mediterranean Climate – Variability and Trends, Springer-Verlag Berlin Heidelberg, Germany, pp. 181-213
19. * * *, 2008, *Clima României*, A.N.M., Edit. Academiei Române, Bucureşti, 365 p.