MONITORING DATA PROVING HYDROCLIMATIC TRENDS IN SIRET HYDROGRAPHIC AREA

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Key words: hydroclimatic risks, global warming, tendency to dryness.

Abstract. By turning an important background hydrometric and pluviometric data the authors analyze the hydroclimatic conditions in Siret's basin system in the last decades and some conclusions on its progress in perspective. These issues, which can also add many more, may constitute the elements that support the theories on the phenomenon of global warming and climate dryness caused by human activities.

Introduction

In the last years, worldwide, are discussed more and more the serious effects on economic development, without providing adequate measures to protect the environment, on future climate evolution. More and more scientists join the idea that the world states should promote appropriate technologies for sustainable development of human society and to take firm action to reduce pollutant emissions that lead to what is generally called "global warming".

The average air temperature increase on Earth is a real phenomenon, attested by numerous specialized research and global warming centers, according to the thermal growth rates, catastrophic: flood in large areas due to melting ice caps, prolonged and catastrophic droughts, and other climate changes.

In Romania also, such research has increased in the last few years, numerous papers being published on the changes produced in the thermal, pluviometric, hydrometric regimes and their impact on future hydroclimatic developments.

Based on the fact that Romania, and mainly Moldova, are located in a hydroclimatic transition zone from oceanic wetter and moderate heat nuances to mainland, with large thermal and pluviometric discontinuities, it is assumed that the SE of the country may be more profoundly affected by climate change. Siret

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basin (the basin managed by the Siret Water Directorate) is located precisely in this part of the country.

For Tg.Mureş, Gregory Makkai (2007) identifies an average air temperature increase for the period 1970-2000, of 0.6^0 C, a value comparable with those obtained by other researchers in Europe.

This increase, according to the author, results from the increasing difference of about 2.4^0 C on maximum temperature trend and decreasing of 1.8^0 C on minimum temperature trend. The same author states that in the period under review the number of summer days with maximum temperatures exceeding 25 ^{0}C increased from 60 to 80 cases annually. He also noted a steady increase from year to year, of the tropical days number, with maximum temperatures exceeding 30^0C, and of the tropical nights with minimum temperatures of over 20 ^{0}C.

Linked to the above, we can state that, in the lower Siret basin (Vrancea-Galați area) the increase in the annual average temperature and number of tropical days and nights are even more significant.

Such growth is emphasized in the book "Climate of Romania" (2008). From the analysis of annual average temperature values from 15 meteorological stations considered representative of the Romanian territory the authors establish that during the 20^{th} century there was an increase of $0.6\text{-}0.8^0$ C. Thus, the increasing trend is lower in western and north-west part of the country and higher in the eastern and southeastern regions. Analysis for Moldova was carried out at meteorological stations Iasi and Roman.

1. Pluviometric regime analysis

At annual level there aren't recorded actual trends of decreasing precipitation, although with quite large variations. We can observe an alternation of dry years with normal years. Thus, in the last 50 years we can mention years with droughts (1961, 1963, 1968, 1986, 1990, 1994, 2000, 2003, 2007), normal years (1965, 1971, 1976, 1986) and rainy years or with important floods (1955, 1969, 1970, 1972, 1973, 1978, 1979, 1981, 1984, 1991, 1996, 1998, 2005, 2008).

Greater discontinuities in rainfall torrentiality and increasing rainfall distribution are observed in the analysis on seasons, months and days.

Regarding the distribution of the seasons, the analysis presented in the Climate of Romania (2008) highlights the major relationships between quantities fallen in the hot season and those from the cold season: 2.13 Iasi; Suceava 2.72; Roman 2.74. These ratios are highest in the country, fact that attests a continental climate.

Torrentiality increasing precipitation can be demonstrated best by analyzing the maximum quantities fallen in 24 hours, which present a particular hydrological significance.

Tab. 1 - Frequency variation inthe occurrence of maximum rainfall in 24 hours in Siret's basin area in the last century (after Olariu, Vamanu, 2003)

Interval	Before 1900	1901-1920	1921-1940	1941-1960	1961-1980	1981-2000	2001-2009
Frequency (%) Xmax.24h>100 l/m^2	1,7	1,7	9,9	8,3	30,5	47,9	30,0
After mixing frequency (%)	7,7	7,7	15,9	14,3	18,5	35,9	20,5

Tab. 2 - Distribution of maximum rainfall in 24 hours on value stages and periods

Flight of precipitation l/m2	Number of cases and frequency (%) on the intervals													
	Before 1900		1901-1920		1921-1940		1941-1960		1961-1980		1981-2000		2001-2009	
	Nr.	%	Nr	%	Nr.	%	Nr.	%	Nr	%	Nr	%	Nr.	%
<100	-	-	-	-	-	-	1	0,8	-	-	-	-	1	0,8
101-120	1	0,8	-	-	2	1,7	3	2,5	26	21,7	32	26,7	18	15,0
121-140	1	0,8	-	-	5	4,2	5	4,2	4	3,3	8	6,7	6	5,0
141-160	-	-	-	-	3	2,5	-	-	4	3,3	10	8,3	5	4,2
161-180	-	-	-	-	-	-	-	-	2	1,7	2	1,7	2	1,7
181-200	-	-	1	0,8	1	0,8	1	0,8	1	0,8	4	3,3	3	2,5
>200	-	-	1	0,8	1	0,8	-	-	-	-	1	0,8	2	1,7
Total	2	1,6	2	1,6	12	10	10	8,3	37	30,8	57	47,5	37	30,8

A study made at 120 pluviometric posts, without considering data as strictly homogeneous lifetime (Olariu, Vamanu, 2003) highlights that the highest frequency of occurrence of maximum rainfall in 24 hours over 100 l/m^2 is after the year 1960 (almost 80%), fact which relates to the anthropogenic factor. We consider 1960 as an approximate limit of transition towards rapid industrialization.

Tab. 3 - Comparable values of average annual flow computed for various periods for Siret river gauging stations

Crt.	River	Hydrometric station	Catchment area F(km^2)	Average altitude Hm(m)	Q calculated for average annual (m^3/s)			
					1965	1971	1991	2008
1	Siret	Siret	1637	572	10,4	10,0	13,0	13,0
2	Siret	Huțani	2152	515	-	12,0	14,4	15,5
3	Siret	Lespezi	5899	513	26,4	28,0	35,8	37,6
4	Siret	Drăgeşti	11899	525	-	57,6	74,9	78,7
5	Siret	Adj. Vechi	20355	647	107	110	137	155
6	Siret	Lungoci	36095	539	151	156	198	212
7	Suceava	Ițcani	2299	629	12,5	13,0	16,3	16,8
8	Moldova	Tupilați	4016	703	25,9	26,2	32,6	32,8
9	Bistrița	Frumosu	2860	1172	30,2	23,3	32,3	38,2
10	Trotuş	Vrânceni	4077	734	23,9	25,0	34,4	34,8
11	Putna	Botârlău	2460	554	12,9	13,4	16,8	15,2
12	Rm.Sărat	Tătaru	1060	295	2,84	2,65	2,80	2,49

Mixing values was made because the number of pluviometric posts increased in time. Corrections have been explained in a previous work (Olariu, Vamanu, 2003). A similar situation can be found also in terms of maximum levels fallen in 24 hours.

Table 2 indicates that in the Siret basin maximum 24 hour rainfall amounts over 100 l/m2 occurred mainly after 1960 (8.3% between 1941-1960, 30.8% between 1961-1980, 47.5% during 1980-2000 and 30.8% after 2000).

Even if we apply the corrections required by non-homogenous length strings of values examined, the increasing of large quantities of precipitation fallen in 24 hours maximum after 1960 is obvious.

For the period 2001-2009 this growth rate is maintained. The percentage of 30.8% typical for these 9 years represents 67.7% if they relate to 20 years.

It should be noted that in the last 9 years there were at least 4 sequences of floods: 2004 and 2005 in Trotuş catchment and on the lower Siret, 2006 in the Vicov-Arbore area and 2008 in the northern half of river Siret Area.

2. Changes in the watercourses hydrological regime

Increasing amounts of precipitation fallen in a short time reflects in a direct way the flow regime, particularly floods. As with rainfall, the annual discharge average level doesn't show a decrease in flow, but a slight increase. Table no. 3 present the mean annual water flow at some gauging stations as they were computed for different time periods: until 1965 under the Siret river basin hydrological monograph, until 1991 and up in 2008 according to data from the archive of DA Siret.

Tab. 4 - The first four maximum water flow values recorded at gauging stations representative of the Siret basin

Crt.	River	Hydrometric station	Maximum flow of floods m3 / s							
			Qmax	Year	Q max	Year	Q max	Year	Q max	Year
1	Siret	Siret	1193	1969	847	1970	828	1978	920	2008
2	Siret	Huțani	866	1969	776	1970	676	1985	813	2008
3	Siret	Lespezi	1133	1969	1080	1974	1028	1978	2414	2008
4	Siret	Drăgești	1900	1969	1768	1991	1949	2005	2930	2008
5	Siret	Adj. Vechi	2220	1969	1960	1975	2450	1991	2300	2005
6	Siret	Lungoci	2670	1969	3186	1970	3270	1991	4650	2005
7	Suceava	Ițcani	1354	1969	1200	1974	720	2005	1710	2008
8	Moldova	Roman	1140	1955	890	1985	1415	1991	1188	2008
9	Bistrița	Frumosu	772	1970	703	1974	452	1978	471	1985
10	Trotuş	Vrânceni	1667	1960	1700	1975	1510	1988	2845	2005
11	Putna	Botârlău	1000	1970	664	1981	1958	2005	858	2007
12	Rm.Sărat	Tătaru	282	1966	266	1969	274	1970	126	2005

From this table we see that there are some differences in the annual average values, calculated on certain periods, but they are increasing and not decreasing, as it would be expected. This is caused by the gradual accumulation of a fund of better quality data.

We also believe that the slight trend of increasing average annual flow occurs due to the contribution made by major floods. Floods are major discharges in a short time, during which evapotranspiration and infiltrations manifests less. So a slight upward trend in average flow is not only the effect of annual precipitation at the richest, but also of the major floods which occurred during the past decades.

Major floods are the effect of an increase in the degree of continentalism and in torrentiality rainfall which occurred more prominent in recent decades. If we watch the first values of maximum flows recorded at gauging stations we'll see that all are after the year 1960, as outlined in the table below (table no. 4).

It can be seen from the table above that the most significant flash floods have occurred, with few exceptions, in the last 3-4 decades. You can also see a deployment of peak values in the last five years (2005, 2008) to those produced previously. Years 2005 and 2008 are characterized by the occurrence of floods of great magnitude. In 2005 flash floods have affected mainly the southern half of the basin (Bistrita river downstream of the Izvorul Muntelui, Trotuş, Putna, Rm. Sarat and the Siret downstream of the confluence with Trotuş) and in 2008 there were floods in the northern half of the territory considered, especially in the basins of Suceava, Moldova and on Siret between the confluences of Suceava and Bistrita.

3. Some case studies

In the following we present briefly three aspects of exceptional floods produced in 1991, 2005 and 2008.

3.1. Floods of 1991. Unlike the general flood of 2005 and 2008 or those with more local character from 2004 (middle basin of the river Trotuş) and 2006 (from the Vicov-Arbore area) which developed after a dry period, in 1991 quasigeneral floods occurred in the eastern area on a background of high precipitation fallen in previous months, which sometimes have exceeded the annual values and led to several local floods in the basins of Bistrita, Tazlău and the Vrancea area.

In late July and early August in 1991 there was a flood in the sub-Carpathian area of Siret basin. This flood had catastrophic effects in the Tazlău basin, with propagations on Trotus and the lower sector of the river below, and the Siret River Cleja-Răcăciuni-Orbeni (Olariu and collaborators, 1994).

Rainfall which generated this flood exceeded 150 l/m^2 in 24 hours at several pluviometric posts. The highest amounts were recorded in Dumbrava-Neamt 234.5 l/m^2, Orbeni-Bacau 196.3 l/m^2 and other stations in Neamt and Bacau counties.

Maximum flow rates that were registered during the floods in many cases went beyond 1% probability, especially in Tazlău basin and some small tributaries of Siret: Cleja Răcăciuni, Orbeni. Accumulation dams were destroyed on the river Tazlău and Mocanu, a tributary of the river Răcăciuni.

In Belcea accumulation's case, the maximum flow was recorded at Helegiu hydrometric station located at the tail of the lake, which was 1550 m^3 / s (1% exceedance probability), and could not be safely transited through this accumulation, clogged at the time for more than 90%. In consequence, the dam was destroyed and downstream was recorded a maximum flow of 3400 m^3 / s, which destroyed the cities here. After the confluence with Trotuş, located about 2 km downstream the dam, the maximum recorded flow was 3750 m^3 / s, also with the exceeding probability of 1% (Olariu and collaborators, 1994).

3.2. Floods in 2005. July's 2005 flood affected especially the southern half of Siret basin and the largest flows occurred on the rivers Bistrita, Trotuş, Tazlău (downstream the confluence with Trotuş) and the Vrancea area (Şuşiţa, Putna, Rm Sarat).

Details of the flood were presented on other occasions (Olariu et al. 2009) so that here we only highlight the great extent of maximum flow and that those (with exceeded probabilities of 1%) were repeated after only 14 years.

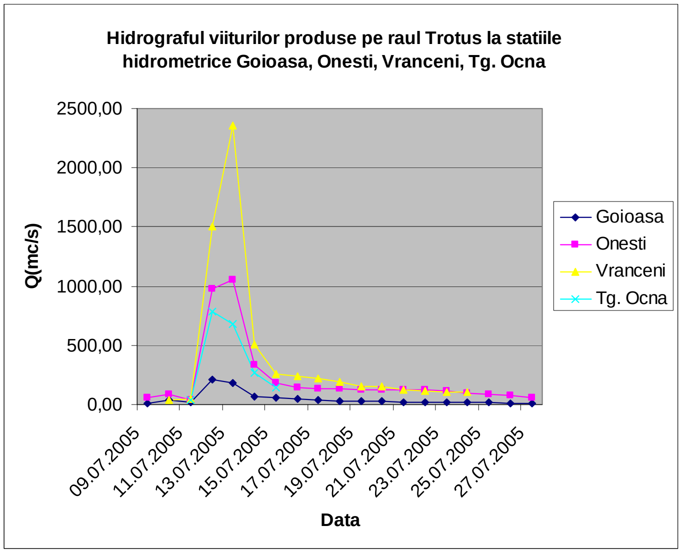

Fig.1 - Trotus river basin floods at gauging stations Goioasa, Onesti, Vranceni, Tg.Ocna

This situation makes the southern part of Siret basin to be registered as an area with great potential risk.

Because on the river Trotuş there have been registered the highest debts, which also caused remarkable increases in the lower sector of the Siret River, we present in Figure no. 1 the hydrographs of floods along this river.

3.3. Flood in 2008. For the northern half of Siret basin, the largest floods showing a particular increase in the degree of rainfall torentiality and discharge, respectively a trend towards hydroclimatic dryness occurred in 2008.

Tab. 5 - Rainfall that caused flash floods in the period 23.07.-3.08.2008 in upper and middle catchment of the river Siret

Crt.	River	Hydromet ric station	Amounts of precipitation fallen in the days (l/m2)							
			22	23	24	25	26	27	28	Total
1	Siret	Siret		13,5	6,3	68,2	16,3	71,6	2,7	178,6
2	Siret	Zvoriştea		11,2	2,9	51,6	12,8	10,7	9,2	98,4
3	Siret	Huțani		11,9	1,3	56,4	22,7	3,5	30,0	125,8
4	Suceava	Brodina		8,4	55,2	102,3	107,7	10,2		284,0
5	Suceava	Vicovu de Jos		8,5	33,4	113,0	135,0	88,0	54,0	431,9
6	Suceava	Țibeni		8,9	1,9	11,8	23,2	27,6	12,6	86,0
7	Suceava	Ițcani	0,1	8,6	1,4	24,1	19,8	1,9	10,4	66,3
8	Putna	Putna	2,5	7,2	55,4	26,6	5,0	33,9		129,6
9	Pozen	Horodnic		15,2	73,2	90,0	81,7	37,2		297,3
10	Sucevița	Sucevița	0,4	13,7	54,8	115,9	73,7	7,3		265,8
11	Soloneț	Părhăuți		10,8	12,8	124,2	13,0	16,8	5,9	183,5
12	St.meteo	Rădăuți	5,2	7,4	65,0	75,4	45,8	3,8		202,6
13	St.meteo	Suceava	7,1	1,6	58,1	77,8	5,2	19,2		169,0

During 23-24.07.2008 the precipitation front with retrogression, very wet, affected mainly the north of Moldova, respectively upper catchments of the rivers

Prut and Siret. The largest flood occurred on the Prut River and Suceava and Moldova catchments.

Catastrophic flash floods on the river Siret Liteni-Bacau sector were formed mainly due to the spread of the Suceava River. On the Siret River, upstream the confluence with the Suceava, maximum flow rate has reached 1000 m^3 / s and in addition, was partially attenuated in Bucecea and Rogojeşti lakes.

It should be noted that during 23-30.07.2008 two floods occurred on Suceava river. Thus, at Ițcani hydrometric station, the two floods occurred during the intervals 24.07.2008 17.00 - 26.07.2008 and 26.07.2008 at 11.00 at 6.00 and 11.00 -30.07.2008 had maximum flows of 1488 m3 / s, respectively 1740 m3 / s.

Rainfall that generated the floods have been rich in Suceava's territory and Ukraine. Most significant values are presented in Table. 5.

Tab. 6 - Maximum flow rates produced during the flood in 2008, compared with peak flows at gauging stations previously produced in the northern half of Siret river basin

Crt.	River	Hydrometric station.	F Km^2	Hm m	Q max 2008 m^3/s	Data	Qmax previously m^3/s	Year	Probability Q max.2008 %
1	Siret	Siret	1637	572	920	27.07	1193	1969	1-2
2	Siret	Huțani	2152	515	813	27.07	866	1969	2
3	Siret	Lespezi	5889	513	2414	27.07	1133	1969	0,1-0,5
4	Siret	N. Bălces.	6906	479	2200	28.07	919	2005	0,1-0,5
5	Siret	Drăgești	11899	525	2930	29.07	1948	2005	0,5-1
6	Suceava	Brodina	366	990	426	26.07	325	1969	2
7	Suceava	Țibeni	1196	730	1118	26.07	520	1995	1-2
8	Suceava	Ițcani	2299	629	1710	27.07	1354	1969	1
9	Brodina	Brodina	142	989	235	24.07	169	1969	2-5
10	Soloneț	Părhăuți	206	467	382	25.07	309	2006	1
11	Moldovița	Lunguleț	144	977	245	26.07	186	1969	2-5
12	Moldovița	Dragosa	462	934	498	26.07	440	1969	2

Data presented in the table above highlight the fact that, for the analysis, flows peak during flood of 2008 are much higher than those known in previous decades, having probabilities of 1% -2% in most cases.

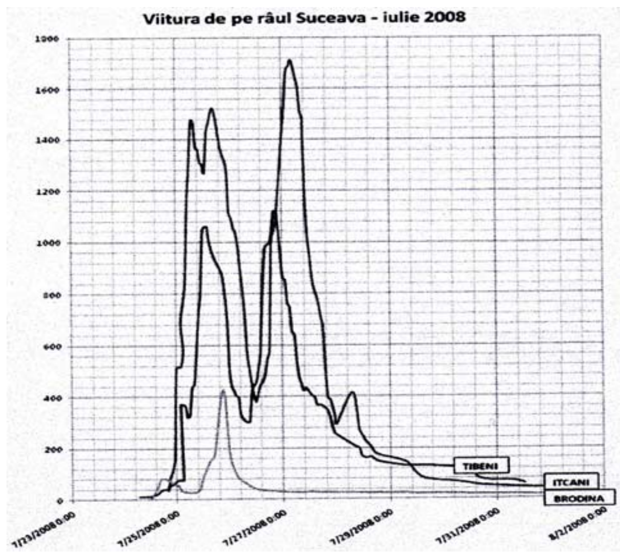

Fig. 2 - The flood from 24-30.07.2008 on Suceava River gauging stations Ţibeni, lţcani and Brodina

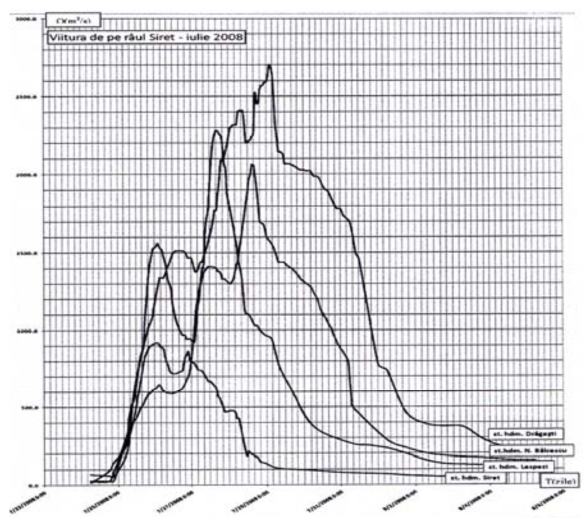

Fig. 3 - Flood period 24.07-03.08.2008 on Siret River

For Siret River, the probability of exceeding the maximum flow is located also just under 0.5%. Such extremely high flow rates, produced amid a period of frequent drought phenomena may be a possible confirmation of the trend of increasing climate variability, global warming and dryness.

Conclusions

Because of its geographical position, Siret catchment has certain characteristics that form factors of increasing rainfall and leaching. Flash floods with increasing frequency in recent decades, are a particularly hydroclimatic important risk factor.

During the maximum flow rates recorded in exceptional flash floods from 1991, 2004, 2005, 2006 and 2008, larger or smaller areas were near or exceeded probability values of 1%, making it necessary to rebuild them.

Based on statistical processing data from existing observations and measurements and result interpretation can be obtained the following few findings:

a. Increase in torrentiality of rainfall and hence of the flow regime;

b. Increase of maximum quantities of precipitation fallen in 24 hours with a special hydrological meaning;

c. Increasing frequency of large floods;

d. The production of high-risk floods: 1991, 2005, 2008;

e. Significant changes in the atmosphere dynamics;

f. Enhancing and territorial expansion of increased droughts.

Such phenomena has been integrated into the overall context of the trend towards global warming and climate dryness, and monitoring data over the last decades are showing such tendencies. The increase in mean annual air temperature of 0,6-0,8^0 C, increased maximum precipitation fallen in 24 hours and maximum flow with probability of 1% and less, represents clear evidence underlying the claims that in parts of the SE of Romania, climate dryness trends and global warming are already obvious.

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