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CLIMATIC TELECONNECTIONS WITH INFLUENCE ON SOME RIVERS FROM SOUTH-EASTERN EUROPE

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ABSTRACT

The influence of Arctic Oscillation, North Atlantic Oscillation, Southern Oscillation and the number of sunspots on river flow rates from the world, from Europe and in some areas of Romania has already been demonstrated. The present study extends the research of this type in the north-eastern of Romania. Arctic Oscillation and North Atlantic Oscillation are stronger in winter, acting through the precipitation on flow. AO and NAO have strong negative correlations with rainfall amounts and river flows. SO and sunspots influence on climate and rivers of the study area have weak statistical significance and occurs more indirectly.

Keywords: hydrological area, climatic factors, NAO, AO, seasonal influences.

RESUMEN

La influencia de la Oscilación del Ártico (OA), la influencia de la Oscilación del Norte del Atlántico (ONA), la Oscilación del Sur (OS) y el número de manchas solares en los caudales de los ríos del mundo, de Europa y de algunas zonas de Rumanía ya han sido demostrados. El presente estudio extiende la investigación de este tipo en el nordeste de Rumanía. La Oscilación del Ártico y la Oscilación del Norte del Atlántico son más fuertes en invierno, actuando a través de la precipitación en el flujo. La OA y la ONA tienen una

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fuerte correlación negativa con cantidades de lluvia y caudales de río. La influencia de la OS y de las manchas solares en el clima y en los ríos del área de estudio tiene un débil significado estadístico y se produce más indirectamente.

Palabras clave: zona hidrológica, factores climáticos, ONA, OA, influencias estacionales.

I. INTRODUCTION

Various climatic phenomena in certain areas of the globe are proved to cause certain climatic and hydrological events in other areas, located at a considerable distance from the source-areas of the phenomena. We examined an area divided between Romania, Ukraine and Moldavia, with a high density of data sources, in order to identify the existence of external influences (outside the study area) on the regional climate and hydrology and, also, the spatiotemporal variations of these influences.

El Niño and La Niña are strongly and repeatedly correlated with the climate of numerous areas around the world (Rasmusson *et al*., 1983), with the simultaneous evolution of precipitation in certain areas, as well as with the flow rates of the rivers receiving waters from these areas (Dracup and Kahya, 1994; Eltahir, 1996; Piechota *et al*., 1997; Chiew *et al*., 1998; Douglas *et al*., 2001; Chandimala and Zubair, 2007).

For the northern hemisphere, the North Atlantic Oscillation (NAO) is one of the most prominent teleconnection models for all seasons (Barnston and Livezey, 1987). Positive and negative phases of NAO are associated with basin-scale variations in the intensity and location of the North Atlantic jet stream, in the location of storms and large-scale modulation of normal models of meridian and zonal heat and moisture transport (Hurrell, 1995), which leads to changes in temperature and precipitation amounts often extended from eastern North America to Western and Central Europe (Walker and Bliss, 1932; van Loon and Rogers, 1978; Rogers and van Loon, 1979).

The Arctic Oscillation (AO) has major influences on the European climate, especially during its negative phases, when cool and dry air masses from polar and sub-polar northern regions move towards the Southern - Southeastern Europe, and determine cooling, runoff and flow decrease being marked by decrease in river flow rates. By representing non-seasonal variations of sea level pressure north of 20ºN latitude, AOI is calculated as the difference of pressure anomalies between the Arctic and marine regions located at 37-45ºN (Wallace, 2000).

It is shown that El Niño Southern Oscillation (ENSO), NAO and AO also affect groundwater levels in Canada (Tremblay *et al*., 2011). Correlations between ENSO, NAO and precipitation amounts, the Great Lakes water levels respectively, are found by Ghanbari and Bravo (2008). Correlations are also found between NAO and the temperature of river springs in Northern Europe (Helama and Holopainen, 2012). By analyzing NAOI and SOI in correlation with fluctuations in sea level in Europe, Tsimplis and Shaw (2008) show that NAOI has relevant correlations with sea level, while SOI has no statistically significant correlation, probably because of the very large distances that are likely to attenuate the influence of the Southern Oscillation.

The NAOI, AOI and SOI are studied by Labat (2010) for the entire globe, the author finding strong correlations between these indices and the flow rate of some great rivers/streams such as the Danube on the Romanian territory. NAO influence on Romania's climate is shown by Mareş *et al*. (2002) as being the strongest during winter months, comparable to the rest of the Europe, by using the Palmer Drought Severity Index analysis. Similar results are obtained regarding the NAO influence on the minimum flow rates in France (Giuntoli *et al*. 2013). The influences of NAO and SO on the Danube in its lower sector is proved by Rimbu *et al*. (2004), Mikhailova *et al*. (2008), Pătruţ (2010).

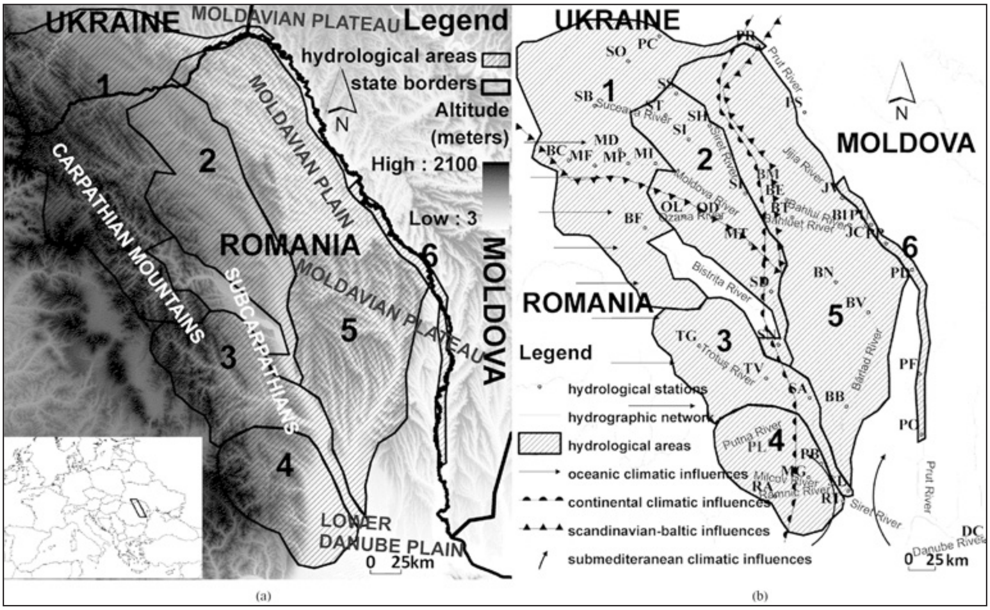
All the studies analyzing the above reviewed influences on the Romanian territory are based on singular, isolated data or, in the best case, on more numerous data sources with only few values for the studied area, but widely distributed on a much larger area compared to the studied one.

II. STUDY AREA

The investigated geographical territory covers a surface of 45 000 km^2 in the North-Eastern part of Romania, the western end of Moldavia and the SW of Ukraine, with elevation values between 2100 m a.s.l. (above sea level) and 3 m a.s.l. Figure 1a.

Figure 1

MAPS OF THE STUDIED AREA: (a) GENERAL LANDSCAPE CHARACTERISTICS. (b) HYDRO-CLIMATIC INFORMATIONS



Own elaboration.

The altitudinal zones generate, from the climatic point of view, three well individualized altitudinal climatic zones: the high and medium mountains (≥ 1000 m a.s.l.) zone, the high, medium and low hills (300-1000 m a.s.l.) zone and the high hilly plains and low plains (3-300 m a.s.l.) climatic zone.

After reviewing the regional climatological research (Apostol, 2000; Mihăilă, 2006) we could underline several regional climate features. On the general background of the temperate climate, external climatic influences exist, depending on the geographical position of the catchments (2cSP - Siret and Prut, with subcatchments), the regional orography and atmospheric zonal and regional dynamics (Figure 1b).

From the thermal point of view, the study area ranged between 0.6°C annual average at Toaca weather station (1897 m a.s.l.) in Ceahlău Mountains (near Frumosu hydrometric station on Bistriţa) and 10.6°C annual average at Galaţi weather station (69 m a.s.l.) in the Danube River's floodplain (near Ceatal Ismail station, on the Danube). Annual precipitation sums varied from 668.2 mm at Toaca to 481.6 mm at Galaţi.

Data on river flow rates (F) were utilized from 45 hydrometrical stations, distributed in the studied region as shown in Table 1 and Fig. 1b. The annual average river flow rates ranged from 6388 $m^3 s^{-1}$ at DC, 213.6 $m^3 s^{-1}$ at SL, 111.9 $m^3 s^{-1}$ at PD (the highest flow rates analyzed) to 0.1 $m^3 s^{-1}$ at BM, 0.18 $m^3 s^{-1}$ at BT, 0.81 $m^3 s^{-1}$ at BE. The average flow rate values in the monitored sectors were 176.4 $m^3 s^{-1}$ including the flow rates of the Danube and 35.2 $m^3 s^{-1}$ without the Danube.

III. DATA AND METHODS

For the analysis of regional climate peculiarities we used air temperature (T) and atmospheric precipitation (P) monthly data available in the CRU database (CRU, http://www.cru.uea.ac.uk/, 20-Dec-12), which was rendered as averages for regions covering 0.5 x 0.5 degrees latitude and longitude. 39 such CRU regions covered almost entirely the investigated area. The available CRU data used covered the 1950-2009 period and it was preferred because it uniformly covers the region with interpolated real values (from meteorological stations) depending on altimetry.

River flow rates data from the 45 hydrometric stations were partly obtained from the National Agency «Romanian Waters», partly from GRDC (The Global Runoff Data Centre, 56068 Koblenz, Germany). Most stations had data from 1950 to 2011 inclusively. The BT, BE and BM stations were from 1950 to only 2007 inclusively. BC, MF, MI, MD, OL, OD, SH and SN were datasets from 1950 to 2009 inclusively. Other exceptions were DC (1950-2008), SC (1950-1995), ST (1991-2009), SO (1953-1995), OP (1979-2011), PD and PU (1975-2005) and PP (1981 -2005).

The data for climatic indexes (NAOI, AOI, SOI) were obtained from NOAA (NOAA, http://www.cpc.ncep.noaa.gov/data/teledoc/telecontents.shtml, http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_ao_index/teleconnections.shtml, 20-Dec-12).

The main direction of approach in the present study was to highlight the major climatic factors hydrographically involved and especially to argue for the hydrological influences in 2cSP induced by NAO, AO and SO. Another approach direction, which remains open for further research, was to identify the hydrologic regime differences in the investigated area, to examine flows and sub-regional evolutionary trends and to quantify teleconnective influences on flows.

Even if for the first direction, the applied work algorithm was simple, for the second one the steps that were followed should be explained in detail. In order to identify the hydrologi-

Table 1
HYDROLOGICAL STATIONS USED IN THE STUDIED AREA

River	Station	Code	River	Station	Code
Siret	Storojineţ	SO	Bârlad	Negreşti	BN
	Siret	SS		Vaslui	BV
	Huţani	SH		Bârlad	BB
	Lespezi	SI	Bahlui	Măgura Carjoaia	BM
	Drăgeşti	SD		Belceşti	BE
	Nicolae Bălcescu	SN		Iaşi	BI
	Adjudu Vechi	SA	Bahlueţ	Targu Frumos	BT
	Lungoci	SL	Bistriţa	Cârlibaba	BC
Prut	Cernăuţi	PC		Frumosu	BF
	Rădăuţi-Prut	PR	Ozana	Leghin	OL
	Stânca	PS		Dumbrava	OD
	Ungheni	PU	Trotuş	Goioasa	TG
	Prisăcani	PP		Vrânceni	TV
	Drânceni	PD	Putna	Colacu	PL
	Fălciu	PF		Boţârlău	PB
	Oancea	PO	Milcov	Goleşti	MG
Moldova	Fundu Moldovei	MF	Râmnicu Sărat	Tulburea	RA
	Prisaca Dornei	MP		Tătaru	RT
	Gura Humorului	MI	Jijia	Victoria	JV
	Tupilaţi	MT		Chipereşti	JC
Moldoviţa	Moldoviţa	MD	Danube	Ceatal Ismail	DC
Suceava	Brodina	SB			
	Ţibeni	ST			
	Iţcani	SI			

Own elaboration.

cal areas, Pearson correlation coefficients (r) were firstly calculated for all hydrometric stations. All correlations were positive. Stations showing ≥0.8 correlation (strong) with other stations were selected from the correlation matrix of all rivers (DC, the only station on the Danube, was eliminated from further calculations because in this sector the Danube didn't show strong correlations with the rivers in 2cSP). These stations were placed on intermediate work maps used to obtain the six hydrological areas in Figure 1. Each intermediate map included the stations in a particular catchment that strongly correlate with each other, as well as other stations located in different catchments, with which the former stations have strong correlations. In order to choose the catchments for the intermediate maps, the main rivers in the studied area were used (Siret, Suceava, Moldova, Ozana, Bistriţa, Trotuş, Putna, Milcov, Râmnic, Bârlad, Prut, Jijia, Bahlui and Bahlueţ rivers) on which all the studied gauging stations were located. Since all relevant stations on the intermediate maps were sets of items, the intersection of sets was used to obtain final hydrological areas with similar hydrological behavior for the constituent stations. For example, if point A showed strong correlation (≥ 0.8) with point B and if B showed strong correlation with point C, but C didn't show strong correlation with A, but with point D, which correlated strongly with A and B, then A, B and D form a hydrological area, while C entered another hydrological area or remained isolated. Consequently, gauging stations formed hydrological areas only if each gauging station from a hydrological area strongly correlated with all stations in the same hydrological area. Such correlations were present for 29 stations (64.4%) out of 45. The isolated points and those with correlations below 0.8 were used next to mark as accurately as possible the boundaries between the hydrological provinces. Since the stations in the same river catchment often have correlations above 0.7, the distribution of the remaining stations to one hydrological area or other was easy.

In Figure 1, one can observe that there are certain areas pertaining to no hydrological region. Two of these areas are centered on the PS station (*case a*) and on the lower sector of the Bistriţa River (*case b*). Both areas were excluded from the hydrological areas because they had reservoirs with significant retention volume, which disrupted the natural river flow regime and therefore the marks of the natural influences external to the studied catchments. The area in the *case a* has a hydrological regime strongly influenced by the existence of the Stânca-Costeşti reservoir dam. The reservoir is on the 2nd place in Romania in what concerns retention volume (1.285 km^3) and, together with other zonal factors, contribute to the separation in terms of hydrological regime of the upper Prut (included in the hydrological area 1) from the middle and lower Prut (area 6). The *case b* area was excluded from the hydrological areas because it had many high-volume anthropogenic lakes (8, of which the largest, Izvoru Muntelui, is the 3rd in Romania in terms of retention volume - 1.23 km^3). This territory consists of the middle and lower parts of the Bistriţa River catchment. The territory between the Danube and the hydrological areas 5 and 6 was not included in any hydrologic area because no data from the local gauging stations were used. There was no reason to include this area in the hydrological area 5, because it is more exposed to sub-Mediterranean influences than area 5, and it also cannot be included in the area 6 because the latter was exclusively delimited according to the data from the Prut River gauging stations (which explains its extension exclusively along the Prut floodplain). Neither can it be included in the hydrological areas 3 and 4 because these are areas with strong mountain climate influences. This territory that cannot be included in the hydrological areas 5 and 6 is characterized by increased aridity due to low elevation values and due to proximity to the Lower Danube Plain and has a climatic behavior affected by retrograde cyclones from the Black Sea. These factors were determinant when establishing the southern limit of the hydrological area 6. This area ends towards the south, immediately downstream the Oancea gauge station, because of the beginning of the decrease in the Prut River flow rate and because of the existence of a distinct hydrological behavior towards the mouth of the mentioned river (Briciu *et al.*, 2011). The boundaries between the hydrological areas 1-5 and between these and the territories not included in any hydrologic area followed the watershed between rivers. The exception was the north-eastern limit of the hydrological area 1, which was drawn across the Prut River floodplain because we had no hydrological data to confirm or refute the existence north of the Prut River (plateau area) of a hydrological behavior of its tributaries similar to that of the tributaries south of the Prut River (predominantly mountainous and high plateau area).

IV. RESULTS AND DISCUSSIONS

IV.1. General climatic characterization

By analyzing the standardized values of air temperature, precipitation and flow rates intermonthly variability (averaged values for the entire study region), we noted the following:

– higher variability of the parameters P (precipitation) and F (flow) – an attribute of the climate with continental influences, compared with T (temperature) (Figure 2).
– a stronger deviation from the average in air temperature during winters (Figure 2a), on the background of polar/Arctic air advections which generate massive temperature drops, cold waves and consequent long lasting thermal inversions, with little precipitation amounts and a significant decrease, close to total interruption of liquid flow (Figure 2b); during summer, subtropical/tropical air advections were common and usually affected the southern and central parts of the studied area; they usually generate rainfall deficit, high evapotranspiration values, hydrologically accompanied by very low flow rates (Figure 2c).
– during summer season, frontal and convective precipitation generate pluviometric and hydrological inputs marked by strong positive deviations (Figure 2b, c); in winter, thermal convection ceases and frontal activity generates solid precipitation that supply the flow only in spring and for this reason the rainfall and runoff are at minimum levels, as indicated by the negative deviations values.

The thermal and pluviometric regime of the study area have already been analyzed thoroughly in various studies, such as Erhan (1979), Apostol (2004), Mihăilă (2006), Dragotă (2008), Săraru (2008), Nistor (2009), Mihăilă and Briciu (2012).

IV.2. Climatic causes of the six hydrological areas behavior

After removing the regions with dominant anthropogenic influence on river flow, we focused our attention on climatic causality of flows. This is, by means of the triggering climatic factors, the macro- and micro-scale synthesis of the most important influences exerted by the nature of local, regional or global sites/processes/phenomena.

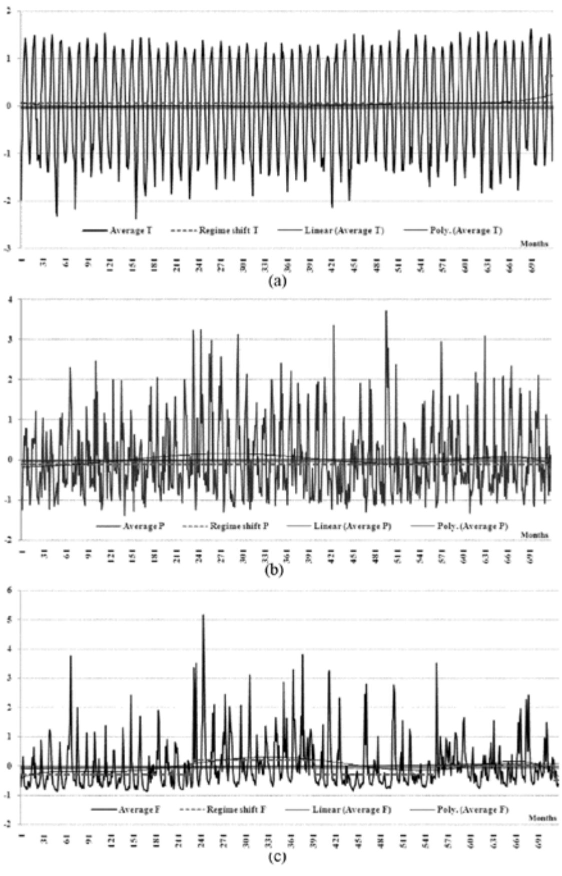
Between climatic and hydrological behavior of the territories enclosed in the hydrological areas the consistencies prevail, some discordant elements ultimately shaping the hydrological identity of the identified areas. We analyzed the correlation of temperature, precipitation and average flow rates of the entire study region with NAOI, AOI and SOI. Correlations results of monthly data for the entire study area are presented in Table 2.

Beside the strong correlations between T, P and F, there are no other relevant correlations except those between NAOI and AOI, which do not show whether or not these indices have some effect on the local climate/hydrography. As expected, the correlations between temperature, precipitation and flow rates are positive, because the wettest months are those of the warm season (especially during May-July).

Concordant P-F evolution results from the monthly covariance analysis of positive (+/+)/ negative (-/-) values of the two parameters, reaching 69% of cases (Figure 3). Covariance was quantified as 5 situation types: 1) both standardized indices of the analyzed parameters had values over the multi annual average of the data string (a+/b+); 2) both indices were negative (a-/b-); 3) the values of the first parameter were positive, the other negative (a+/b-); 4) the inverse of 3) (a-/b+), and in the last case, 5) contexts implying 0 values. Infiltration and groundwater flow regulate P-F asynchronous relations.

Figure 2

EVOLUTION OF (a) AIR TEMPERATURE, (b) PRECIPITATION AMOUNTS AND (c) FLOW RATES (STANDARDIZED MONTHLY AVERAGES FOR THE PERIOD 1950-2009) ANALYZED USING LINEAR AND 6TH DEGREE POLYNOMIAL TRENDS



Own elaboration.

Table 2
F CORRELATIONS - TELECONNECTIVE PARAMETERS IN 2CSP (BASED ON THEIR STANDARDIZED MONTHLY VALUES) BETWEEN 1950-2009

	T	P	F	NAOI	AOI	SOI
T	1					
P	0.56	1				
F	0.30	0.57	1			
NAOI	-0.01	-0.08	0.01	1		
AOI	0.14	-0.09	0.02	0.60	1	
SOI	-0.01	0.01	0.05	0.00	0.09	1

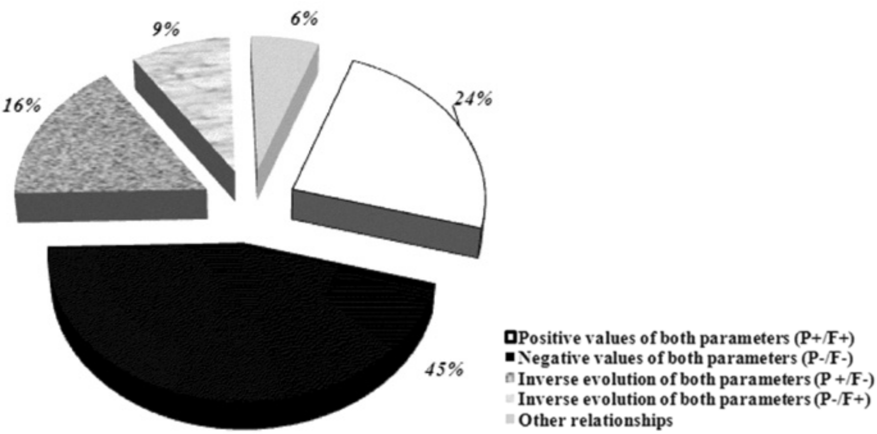
Own elaboration.

The graphic representation of the historical evolution of standardized average flow rates and standardized average precipitation amounts for the whole region (Figure 4a) confirms the approximately synchronous evolution of the two theoretical parameters.

The in-depth analysis, for the whole region and for each hydrological area separately, of Pearson correlation coefficient between precipitation and flow rates for each month showed that usually the warm season (April-September) is the one having T-P synchronization and that some areas have, more than others, a much stronger T-P correlation.

Thus, in Table 3 one can observe that there is a much stronger correlation between precipitation and flow rates in the hydrological areas located entirely or partly in the Carpathian region. The frequently torrential regime of the rainfall interrupting periods of dryness and drought, the prevalence of strongly inclined slopes that limit infiltration, combined with a high degree of deforestation in the hydrological area 4 sector of the Carpathians and Sub-Carpathians cause a rapid flow of precipitation through rivers and justify why area 4 has the strongest correlations between F and P.

Figure 3
MULTIANNUAL MONTHLY COVARIANCE OF P – F IN 2CSP (1950-2009)



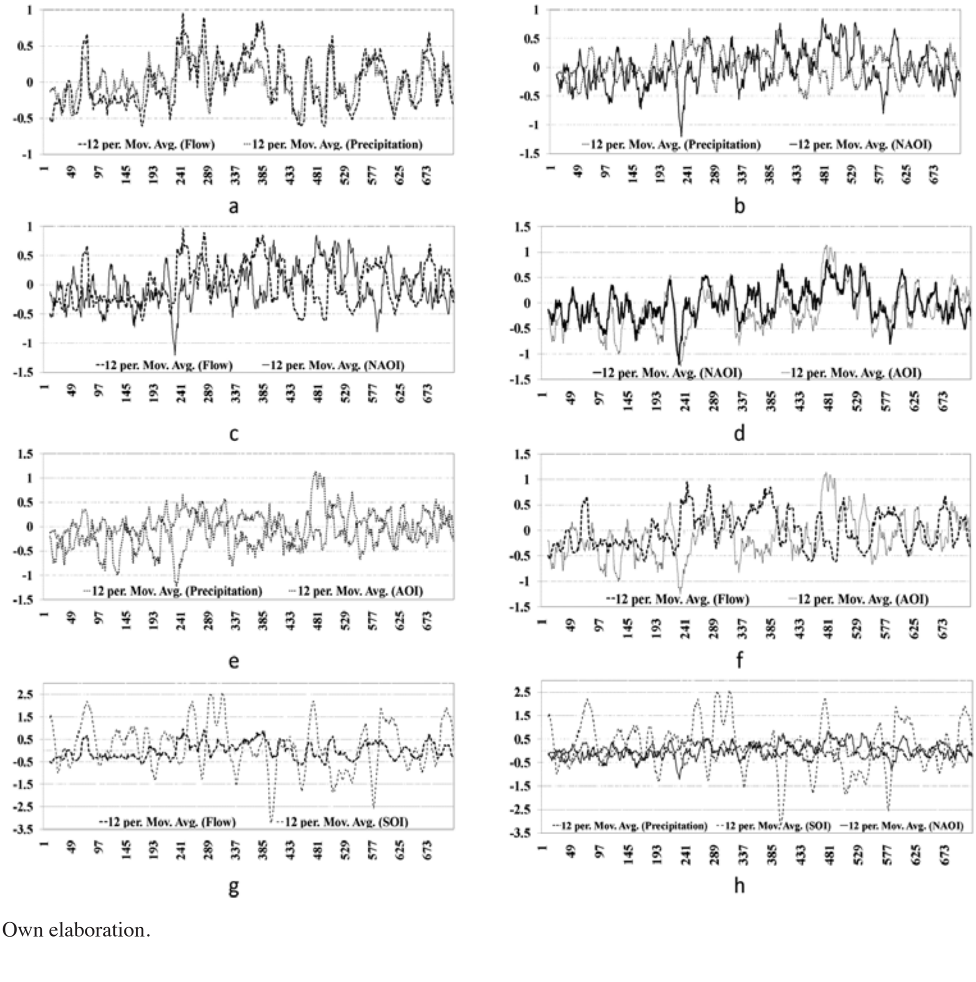
Own elaboration.

In contrast, area 6 shows the smallest correlations because the flow in middle and lower sectors of Prut River is dependent to a large extent on human interventions at Stânca-Costeşti Dam and because of the low discharge tributaries that Prut receives in this sector, which cannot impose the regional climatic signal.

Area 5 is characterized by lower F-P correlation values due to the fact that evapo(transpi) ration is higher than in areas 1-4. Likewise, the hilly plain and plateau area is highly permeable and the percolation/infiltration processes are very active, the runoff on the topographic surface is slower, much of it being transferred underground, breaking and complicating the P-F direct connective mechanism.

Figure 4

INTER-MONTHLY EVOLUTION OF MOVING AVERAGES OF P AND F (a), P AND NAOI (b), F AND NAOI (c), NAOI AND AOI (d), P AND AOI (e), F AND AOI (f), F AND SOI (g), P AND SOI, NAOI (h) – HORIZONTAL AXIS IN NUMBER OF CONSECUTIVE MONTHS BETWEEN 1950 AND 2009



Own elaboration.

Correlations between F and T are much weaker and of double sign. Generally, in winter there is a positive correlation between the two parameters due to the fact that rising temperatures lead to snow and ice melting and increase in river flow rates, while in summer high temperatures imply higher evaporation from rivers (and lakes) and also evapo(transpi)ration from the surface of the catchment. Because summer also means heavy rainfall, correlations established between the 2 parameters get complicated and become ambivalent and less representative.

Relevant correlations are established between P and NAOI, AOI respectively. Correlation matrices in Table 4 show a strong, negative correlation between the indexes and precipitation amounts in the cold season. Moreover, there is a gradual and relatively constant change of sign between warm and cold season. The warm season shows extremely weak, positive correlations, indicating that the 2 oscillations of the Northern Hemisphere affect regional climate in the cold season, an observation also confirmed by Mareş *et al*. (2002) and Pătruţ (2010).

Annual average correlations for the entire study area are equal to -0.24 for AOI-P and -0.14 for NAOI-P. One can observe that the calculation of annual average correlation for the entire study area based on averaging the average monthly correlations for each hydrological area (Table 4) generates a whole region correlation coefficient between parameters that is higher than the simple correlation of two sequences of consecutive monthly values for the entire study area (Table 3).

Table 3

MONTHLY CORRELATION COEFFICIENTS BETWEEN F-P FOR THE HYDROLOGICAL AREAS 1-6 (1950-2009)

	1	2	3	4	5	6
I	-0.02	-0.08	0.05	0.35	0.00	-0.14
F	-0.05	-0.18	-0.12	0.17	0.06	-0.11
M	0.25	0.21	0.35	**0.51**	0.31	0.02
A	0.33	0.39	0.49	**0.53**	0.44	0.16
M	**0.66**	**0.71**	**0.68**	**0.73**	**0.67**	0.19
I	**0.65**	**0.62**	**0.53**	**0.52**	0.45	0.28
I	**0.60**	**0.63**	**0.64**	**0.72**	**0.56**	0.49
A	**0.56**	0.43	0.46	**0.65**	0.42	0.21
S	**0.59**	**0.61**	**0.59**	**0.72**	0.41	0.28
O	**0.52**	0.43	**0.58**	**0.62**	0.49	0.26
N	0.42	0.47	0.29	**0.64**	0.20	0.29
D	0.20	0.24	0.25	**0.55**	0.21	0.13

Own elaboration.

The annual correlations blur a seasonal oscillation in the correlation intensity. Note that there are two peaks of AOI and NAOI influence in the cold season (Table 4). The analysis of AOI-F and NAOI-F correlations showed that these have approximately the same trend throughout the year for each region, but AOI and NAOI influences were weaker on F than on P: 20% weaker for F-AOI and 14% weaker for F-NAOI. The most significant changes occurred in January and February (-46% and -45%, respectively, for AO influence; -31% and -34%, respectively, for NAO influence). In addition, the amplitude between the maximum and the minimum of changes in oscillations influence on P and F is 1.8 times higher for AOI. Based on observations, we can say that the more powerful the influence of oscillation (AO), the more variable the evolution of the related index values is (in our case, AOI).

Table 4

MONTHLY COEFFICIENTS OF CORRELATION OF A. AOI-P AND B. NAOI-P FOR THE HYDROLOGICAL AREAS 1-6 AND 2CSP (1950-2009)

a.	1	2	3	4	5	6	2cSP	b.	1	2	3	4	5	6	2cSP
J	-0.46	-0.48	-0.5	-0.49	-0.55	-0.52	-0.5		-0.37	-0.36	-0.34	-0.3	-0.39	-0.36	-0.35
F	-0.46	-0.45	-0.48	-0.43	-0.47	-0.46	-0.46		-0.43	-0.38	-0.35	-0.25	-0.33	-0.33	-0.34
M	-0.36	-0.34	-0.28	-0.24	-0.28	-0.31	-0.3		-0.27	-0.26	-0.18	-0.12	-0.15	-0.17	-0.19
A	0.02	-0.04	-0.06	-0.04	-0.04	-0.01	-0.03		-0.24	-0.23	-0.12	-0.09	-0.19	-0.21	-0.18
M	-0.04	-0.09	-0.15	-0.14	-0.16	-0.18	-0.13		0.02	-0.03	-0.11	-0.13	-0.1	-0.09	-0.07
J	0.02	0.03	-0.06	-0.07	-0.01	-0.03	-0.02		0.07	0.15	0.16	0.19	0.17	0.08	0.14
J	0.01	0.07	0.1	0.1	0.09	0.02	0.07		-0.05	0.02	0.1	0.12	0.1	0.06	0.06
A	-0.05	-0.06	-0.09	-0.07	-0.07	-0.12	-0.08		-0.03	0.01	0.09	0.19	0.12	0.06	0.07
S	-0.44	-0.45	-0.41	-0.36	-0.43	-0.44	-0.42		-0.25	-0.23	-0.14	-0.09	-0.16	-0.19	-0.18
O	-0.34	-0.39	-0.26	-0.22	-0.26	-0.34	-0.3		-0.43	-0.41	-0.27	-0.22	-0.28	-0.36	-0.33
N	-0.32	-0.42	-0.46	-0.39	-0.42	-0.38	-0.4		-0.17	-0.13	-0.08	-0.03	-0.09	-0.1	-0.1
D	-0.39	-0.26	-0.21	-0.22	-0.29	-0.28	-0.27		-0.26	-0.13	-0.06	-0.08	-0.15	-0.17	-0.14

Own elaboration.

Analyzing the graphic analysis for the entire region, P-NAO and F-NAO teleconnections are evident, showing that the oscillations action on precipitation characteristics is strong enough to influence flow evolution. The 12-month moving averages successively delayed by one month help establishing these relations of interdependence between P, F and NAOI (Figure 4b, c).

The positive NAO phase is characterized by pressure values below normal at high latitudes of the North Atlantic and pressure values above normal at subtropical and temperate latitudes of the North Atlantic, the Eastern United States and Western Europe, while highly positive phases of NAO tend to be associated with temperatures and precipitation values below-average in southern and central Europe. The Siret and Prut catchments fall under the influence of anticyclonic fields extended from the Atlantic to Siberia, which direct the Icelandic mobile cyclones towards their northern terminal part and obstruct Mediterranean- Pontic cyclonic advections. Subtropical dry air and continental polar air reaching anticyclonic areas over the east-Carpathian territories significantly diminish convective processes and frontal activity, thus favoring cool and dry weather with low river flow rates.

Monthly data modeled as moving averages showed that during the positive/highly positive phases, atmospheric precipitation (Figure 4b) and flow rates in the Siret and Prut catchments (Figure 4c) are low or very low.

The monthly covariance analysis of NAOI-F (Table 5) for the period 1950-2009 showed that, generally, during the positive NAO phases (NAOI+) precipitation and flow rates decrease (F-). As percentage, this inverse covariance becomes increasingly relevant from the statistical point of view as we narrow the reference period from the annual resolution ((NAOI+)-(F-) = 31% of cases) and focus our attention on the cold semester ((NAOI+)-(F-) = 42% of cases) and winter months ((NAOI+)-(F-) = 49% of cases). This is most relevant connection between NAO and F for the studied area. Pătruţ (2010) also observe the existence of a negative correlation between NAO and the flow rate of the Danube in Romania.

The slight movement towards south, into the Mediterranean area, of a high atmospheric pressure belt, an eastward extension of Azores anticyclone, causes low intensity cyclonic advections in 2cSP. Under these circumstances, even if NAOI have positive values, the standardized indices of precipitation and flow rates within 2cSP increase to values higher than one standard deviation. But statistics showed that these situations occur quite rarely, having low/very low percentages on an annual basis ((NAOI+)-(F+) = 16% of cases), on semester basis (in the cold semester (NAOI+)-(F+) = 8% of cases), and on seasonal basis (winter: (NAOI+)-(F+) = only 4% of cases).

Table 5

MONTHLY COVARIANCE OF NAOI AND F STANDARDIZED VALUES IN 2CSP (1950-2009) FOR DIFFERENT TEMPORAL SCALES (YEAR, COLD SEMESTER, WINTER)

	(NAOI+) -(F+)	(NAOI-) -(F-)	(NAOI+) -(F-)	(NAOI-) -(F+)	Other relationships
Annual (%)	16	***32***	**31**	16	5
Cold semester (O, N, D, J, F, M) (%)	8	***38***	**42**	8	4
Cold season (D, J, F) (%)	4	***38***	**49**	5	4

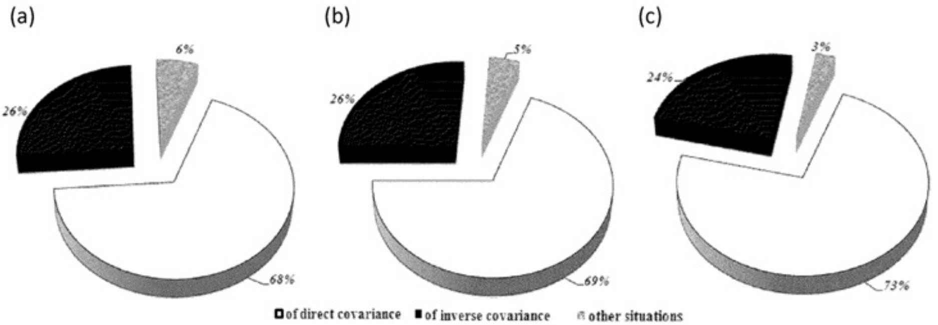
Own elaboration.

The negative phase of NAO reflects an opposite distribution pattern of values for pressure and pressure anomalies over 2cSP. Opposite patterns of temperature and precipitation anomalies are typically observed during strong negative phases of NAO. During these phases, the high pressure center over the central-north Atlantic narrows significantly, as well as the low pressure center from the Icelandic area. The withdrawal of high atmospheric pressure field (ridges of the Azores anticyclone) towards South-Western Europe allows the installation in Central-Eastern Europe, especially during cold season, of the Eurasian anticyclone ridges, which send very dense and cold air masses in the area located outside the Carpathians (Moldavian Plateau, Romanian Plain) and thus favor thermal inversions of significant size and duration, characterized by prolonged frost, little precipitation and stratiform clouds. The

NAOI negative and strongly negative phases are usually marked, for 2cSP, by precipitation values and flow rates below average (Figure 4c). The NAOI-F covariance (Table 5) showed that, as a rule, during the negative NAO phases (NAOI -), in 2cSP, precipitation and flow rates diminish (F-). These situations are statistically representative for the annual level (NAOI-)-(F-) = 32% of cases), for the semester level (cold semester: (NAOI-)-(F-) = 38% of cases) and for the seasonal level (winter: (NAOI-)-(F-) = 38% of cases). This is the second connection in what concerns relevance between NAO and F in 2cSP. There are also situations when, during negative NAO phases, standardized indices of precipitation and flow rates for 2cSP are positive. Their share is reduced as the coldest intervals of the year are included in the analysis (from 18% on an annual basis to 8% and 5% cases during cold semester and season, respectively (Table 5)).

AOI varies over time, with a particular periodicity, approximately synchronous with NAOI (Figure 4d, 5). If the AOI is negative, pressure tends to be high in the polar region, zonal winds developed longitudinally are usually weak and cold polar air circulation towards middle latitudes, the latitudinal circulation, is intensified. Polar air (with an annual frequency equal to 30%, according to Topor and Stoica (1965)) can reach over 2cSP on the following paths: direct polar path (33.2% of all polar circulation), polar returned path (41.7% of the total polar air movement) and ultra-polar (25.1% of all polar circulation cases) (Topor and Stoica, 1965).

Figure 5
NAOI – AOI COVARIANCE FOR THE PERIOD 1950-2009.
(a) MULTIANNUAL MONTHLY. (b) COLD SEMESTER - O, N, D, J, F, M. (c) WINTER MONTHS - D, J, F



Own elaboration.

For the first and third paths, cold and dry polar air moves from its original areas (from NNW, N and NE relative to 2cSP), increasing its continental characteristics in what concerns humidity/rainfalls. For the second path, the advection over the North Atlantic, the Baltic Sea, Atlantic Ocean and the Mediterranean Sea converts cold polar air into warm and humid air, that generates warming and rainfalls, followed by increased 2cSP flow rates. During the interval in which AOI values are cumulatively negative and water temperature in the Central and Eastern Mediterranean is high, cyclonic activity on the Mediterranean Sea intensifies, generating subtropical humid air advections which come in contact with continental polar air on the front line (often located over the central-southern part of 2cSP) and the weather becomes warmer, with high precipitation amounts (liquid, mixed or snow, often accompanied by blizzard), river flow rates rise slightly over the normal value of the reference period. The dynamic crossroads where 2cSP is located complicates significantly the very precise quantification of these teleconnections, (AOI-)-(F+), reflected by the covariance cases of the standardized indices of flow rates (16% on an annual basis, 9% for the cold semester and 7% in winter).

Between Topor and Stoica's statistics from 1965, based on the analysis of atmospheric pressure systems across Europe during 1938-1962, and those presented in Table 6, which are based on AO and F standardized indices, similarities and differences can be found. Similarities reside in the great importance that both studies attribute to polar circulation (Topor and Stoica, 1965) and to AO, respectively, (according to the data in Table 4, AO is the most obvious teleconnection for P and F in 2cSP). Differences arise from: different periods to which the two studies report (1895-1955 and 1950-2009, respectively), different approaching methodology of polar circulation/arctic oscillation. Topor and Stoica (1965) calculated the multi-annual weight of polar circulation, while our analysis is not synoptic, but focused on statistics of monthly standardized AO values. This leads to a smaller weight in the present study of the (AOI-)-(F-) and of (AOI-)-(F+) covariance cases compared to the research works to which we refer. (AOI-)-(F-), which in our opinion are mostly an attribute of direct polar circulation and ultra-polar circulation (32% for the annual level, 43% for the cold semester and 53% for the winter months) is comparable with, but less than 58.3% polar circulation cases according to Topor and Stoica (1965). (AOI-)-(F+), which in the study of Topor and Stoica (1965) represents retrograde polar circulation, with 41.7% of cases, in our study it ranges between 16 and 7% at annual and cold semester/season, respectively. The (AOI-)-(F-) covariance is the most significant connection between AO and F in 2cSP.

Table 6

MONTHLY COVARIANCE OF AOI AND F STANDARDIZED VALUES IN 2CSP (1950-2009) FOR DIFFERENT TEMPORAL SCALES (YEAR, COLD SEMESTER, WINTER)

	(AOI+)-(F+)	(AOI-)-(F-)	(AOI+)-(F-)	(AOI-)-(F+)	Other relationships
Annual (%)	14	**32**	28	16	10
Cold semester (O, N, D, J, F, M) (%)	6	**43**	34	9	6
Cold season (D, J, F) (%)	2	**53**	33	7	5

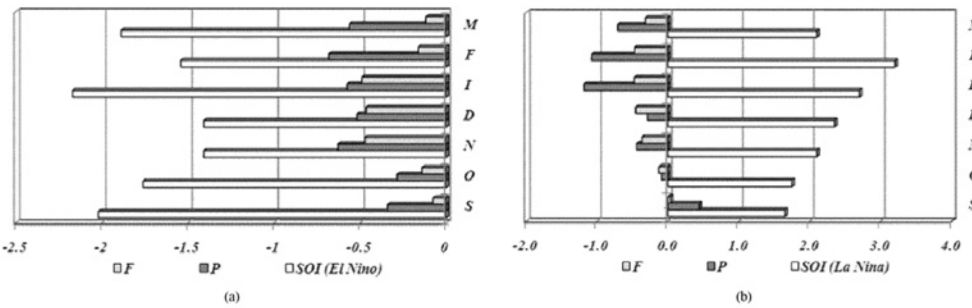
Own elaboration.

When the AOI index is positive, surface pressure is low in the polar region. This helps the middle latitude jet stream to flow strongly and consistently from west to east, thus keeping the cold Arctic air locked in the polar region. In the lower atmosphere, outside the Carpathians, anticyclonic pressure systems are dominant, which often have corresponding systems in the upper troposphere. The result is the cool and dry weather (Figure 4e) which results in low runoff and flow values, as well as flow rates usually below the normal value of the reference interval (Figure 4f).

(AOI+)(F-) represented approximately 1/3 of the AOI-F covariance cases (annually: 28% of cases; in the cold semester: 34% of cases; in winter: 33% of cases (Table 6). This is the second significant connection between AO and F in 2cSP.

There are situations in which, during positive AO phases the 2cSP flow rates increase, as a result of cyclonic Mediterranean or retrograde advections. But they are less statistically relevant (annually = 14%, the cold semester = 6%, winter months= 2% (Table 6).

Figure 6
CORRELATIONS ESTABLISHED BETWEEN SOI AND P, F IN 2CSP.
(a) DURING EL NIÑO EPISODES (SOI-)-(P-), (SOI-)-(F-). (b) DURING LA NIÑA EPISODES (SOI+)-(P-), (SOI+)-(F-)

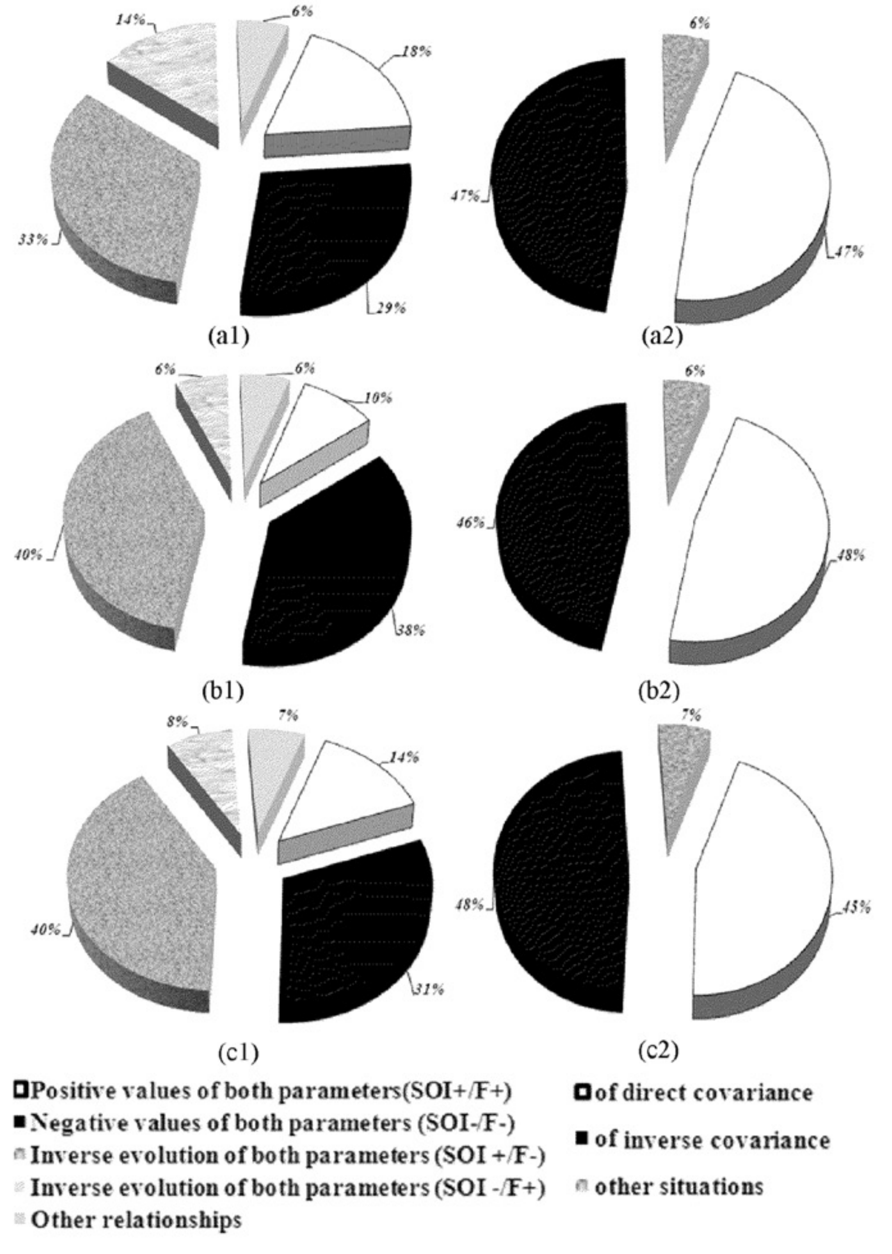


Own elaboration.

In analyzing the influence of the Southern Oscillation on climate and local (2cSP) flow rates, we used standardized SOI monthly values calculated according to the Australian Bureau of Meteorology data. Persistent negative values of SOI often indicate El Niño episodes (1951-1952, 1957-1958, 1965-1966, 1969-1970, 1972-1973, 1976-1977, 1982-1983, 1986-1987, 1991-1992, 1994-1995, 1997-1998, 2002-2003, 2006-2007).

The positive SOI values are associated with La Niña episodes (Ex.: 1988-1989, 2007-2008). By averaging the SOI values during El Niño episodes (13 episodes, with a focus on J-M interval, during which the SO oscillation reaches its peak) and the standardized indices of precipitation (P) and flow rates (F) from 2cSP, we observed that, in such intervals, both precipitation amounts and flow rates are below normal (Figure 6). It is possible that such teleconnections (SOI-)-(P-), (SOI-)-(F-) do not exist in such an obvious manner as shown by the statistics. It is possible that in this situation we only discuss about a statistical coincidence that hides other teleconnective mechanisms or local/regional influence of climate-generating factors. This observation is also supported by the statistics of (SOI+)-(P-), (SOI+)-(F-) covariance cases in 2cSP (Figure 6b, resulted from the mediation of only the two La Niña cases previously mentioned), which dilute the substance of conclusions that can be drawn from Figure 6a.

Figure 7
SOI-F COVARIANCE FOR THE PERIOD 1950-2009.
(a1, 2) ANNUAL SCALE. (b1, 2) COLD SEMESTER SCALE - O, N, D, J, F, M. (c1, 2) WINTER MONTHS SCALE - D, I, F



Own elaboration.

For 2cSP, pluvial-hygrometric influence of SO can hardly be quantified primarily due to the huge distance (12 000 km) between the SO area of manifestation and 2cSP. In addition, SO influences are diminished by the mechanisms of the convective cells of the equatorial Pacific and Eastern European temperate zones, by a series of orographic obstacles and by azonal climates.

Not even the graphical analysis (Figure 4g) showed clear relationship of direct or inverse proportionality between SOI and flow rates from 2cSP.

Monthly covariance between SOI and F (720 cases processed) is weakly expressed (Figure 7), annually (Figure 7a1, a2), at semester level (Figure 7b1, b2), but also for J, F, M months (Figure 7c1, c2). From their careful analysis we couldn't distinguish a clear teleconnective mechanism between SO and F in 2cSP. Moreover, they do not suit the teleconnective climate reality whose consequences are explained and known to other areas or geographic regions.

The attempt to identify constantly repeatable graphic correlations between SOI and NAOI on the one hand and SOI–P in 2cSP on the other hand (Figure 4h) showed no strong links. In agreement with the observations made, we may state that the SO influence on P, F in 2cSP is weak, indirect and difficult to quantify.

We examined the correlation between the correlations of various parameters in order to observe if they have similar annual evolution despite their low/high values. As seen in the case of NAO influence on river flow, some indices or parameters may be relevant, but with an extremely weak signal which sometimes cannot have a definite meaning unless a similarity with another index/parameter similar in manifestation, but more intense, is shown. For example, the correlation of -0.86 between T-F and P-F indicates that there is an approximately anti-synchronous evolution between the changes of the T and F correlation during an average year (12 monthly values) and P and F correlation, respectively: when temperature increases, its correlation with flow rates decreases as evapo(transpi)ration occurs; however, when rainfall increases, flow rates increase as well. This negative correlation is clearly seen in Table 7.

Table 7

F-T, F-P CORRELATIONS IN 2CSP

	I	F	M	A	M	I	I	A	S	O	N	D
F-T	0.22	0.41	0.03	-0.18	-0.27	-0.26	-0.28	-0.24	-0.36	-0.10	-0.05	0.12
F-P	0.03	-0.04	0.27	0.39	0.61	0.51	0.61	0.46	0.53	0.48	0.39	0.26

Own elaboration.

The correlations between correlations established for the whole region are presented in Table 8. We will examine only the correlations involving F in order to see to what extent teleconnective factors affect flow regime. The strongest correlation is established between [F-AOI] and [F-NAOI] ÷ 0.85 (Table 8). Thus, we can deduce that proximal oscillations (northern - AO, western - NAO) act on the flow regime mainly through two intermediate meteorological elements – atmospheric precipitation and air temperature.

Table 8
MULTIPLE CORRELATIONS BETWEEN F AND CLIMATIC ELEMENTS (T, P) OR TELECONNECTIVE PARAMETERS IN 2CSP

	T-P	T-F	T-NAOI	T-AOI	T-SOI	P-F	P-NAOI	P-AOI	P-SOI	F-NAOI	F-AOI	F-SOI
T-P	1											
T-F	0.41	1										
T-NAOI	0.12	0.61	1									
T-AOI	-0.08	0.49	0.83	1								
T-SOI	0.26	0.16	-0.09	-0.36	1							
P-F	-0.30	-0.86	-0.65	-0.62	-0.14	1						
P-NAOI	-0.32	-0.64	-0.40	-0.51	-0.04	0.62	1					
P-AOI	-0.26	-0.61	-0.44	-0.63	0.23	0.63	0.77	1				
P-SOI	-0.08	-0.51	-0.19	-0.20	-0.24	0.56	0.15	0.04	1			
F-NAOI	-0.22	-0.21	-0.12	-0.02	-0.01	0.21	0.49	0.28	-0.19	1		
F-AOI	-0.18	-0.14	-0.09	-0.08	-0.07	0.16	0.48	0.35	-0.28	0.85	1	
F-SOI	0.07	0.13	0.09	0.03	-0.14	-0.04	-0.18	-0.12	0.17	-0.20	-0.06	1

Own elaboration.

Details of the correlations between correlations involving standardized indices of F for each hydrological area are given in Table 9. The attempt to regionalize 2cSP flows based on purely teleconnective statistical arguments would not render the expected results, firstly because teleconnective factors leave their mark on large territories, and their influence cannot be stopped at a river valley or a contact between plain and plateau subunits, between plateau and hilly areas etc. Among physical-geographical factors, mountain ranges (Carpathians, in our case) are able to reduce or bar these influences, but the entire study area is on the same side of the Carpathians. In this case, the correlative differentiations between the standardized indices of oscillations/precipitation/flow of any two areas of 2cSP are imposed by the nature of the active/topographic surface.

Table 9 rather reflects the extent to which the identified hydrological areas respond to the genetic factors matrix responsible for flow, of which we highlighted the teleconnective factors. Neglecting this fact would require explaining certain outstanding differences between the same parameters in areas not far from one another (e.g. [F-NAOI]-[P-AOI] correlations are 0.17 in the hydrological area 6 and 0.75 in the hydrological area 4, as well as [F-AOI]-[P-NAOI] correlations, which are 0.29 in the hydrological area 6 and 0.72 in the hydrological area 4 etc.). This is difficult to accomplish in the present state of scientific knowledge of the study area.

IV.3. The hydrologic behavior of 2cSP and of the 6 hydrological areas

The existence of different climatic influences in the studied area and the altitudinal zonation of climate create the hydrological regime of rivers and allow a theoretical flow regionalization in 2cSP. Indeed, the result of mathematical and logical operations allowed us to identify six provinces partially overlapping on different altitudinal zones and climatic influence zones of various origins.

Table 9
MULTIPLE CORRELATIONS BETWEEN F AND CLIMATIC ELEMENTS (T, P) OR TELECONNECTIVE PARAMETERS IN THE 6 HYDROLOGICAL AREAS AND IN 2CSP BETWEEN 1950-2009

	1	2	3	4	5	6	**2cSP**
				T-F			
T-NAOI	0.66	0.67	0.74	0.55	0.47	0.61	**0.61**
				T-F			
P-F	-0.91	-0.95	-0.89	-0.66	-0.84	-0.92	**-0.86**
				T-NAOI			
P-F	-0.72	-0.68	-0.62	-0.57	-0.64	-0.68	**-0.65**
				T-AOI			
P-F	-0.62	-0.66	-0.55	-0.47	-0.65	-0.77	**-0.62**
				T-F			
P-NAOI	-0.69	-0.65	-0.65	-0.52	-0.56	-0.74	**-0.64**
				P-F			
P-NAOI	0.73	0.68	0.57	0.50	0.58	0.67	**0.62**
				P-F			
P-AOI	0.64	0.59	0.68	0.52	0.76	0.61	**0.63**
				T-F			
P-SOI	-0.64	-0.62	-0.48	-0.30	-0.44	-0.57	**-0.51**
				P-F			
P-SOI	0.60	0.69	0.54	0.56	0.41	0.55	**0.56**
				P-NAOI			
F-NAOI	0.53	0.28	0.66	0.75	0.54	0.17	**0.49**
				P-NAOI			
F-AOI	0.44	0.31	0.51	0.72	0.60	0.29	**0.48**
				F-NAOI			
F-AOI	0.82	0.88	0.84	0.88	0.82	0.86	**0.85**

Own elaboration.

Thus, the hydrologic area 1 is of certain Scandinavian-Baltic influence (about 2/3 of its surface: the north central, northern and north-eastern parts). The Scandinavian-Baltic influence can be attributed to direct polar circulation (less to ultra-polar circulation) manifested especially in the cold season (mainly winter) during negative AO phases. We must consider, however, that in the central-western, western and southern parts oceanic influences (via the NAO and AO) are important. The two monitored hydrological stations that are outside the mountain area belong to the two major rivers in NE Romania (Siret and Prut), which certainly have here a hydrological regime dominated by the mountains in the immediate vicinity, from which they originate. Hydrological area 1 is, therefore, defined by a complex mountain climate with Scandinavian-Baltic/oceanic influences characterized by: long annual interval with possible frost occurrence (September to June), long lasting snow layer (late October - middle of April), relatively high precipitation amounts (600-1000 mm) brought by the Atlantic cyclones detached from the polar front, positive annual balance (100-500 mm) between rainfall and evapotranspiration, few draught intervals, much diminished continental influences and the natural landscape characteristics (large forested areas, ~ 650 m a.s.l.).

The hydrological area 2 is located at the border between Scandinavian-Baltic influences (predominant in the cold season) and continental climatic influences (which amplify the Scandinavian-Baltic influences in winter) covering an exclusively plateau topographic surface (~350 m a.s.l.) which allows strong influences of the Eurasian anticyclone in the cold season, influences affecting river flow rates through the prolonged freezing regime, while in the warm season the relatively high frequency of anticyclone time intervals causes decrease in flow rates through lack of rainfall. In the hydrologic area 2, ultra-polar advections add to the direct polar ones, being second most important. The AO influence (more frequent through negative phases, less frequent through positive phases) is the most relevant climatic-hydrological teleconnection of this area. However, the influence of NAO in its negative phase ought not to be ignored.

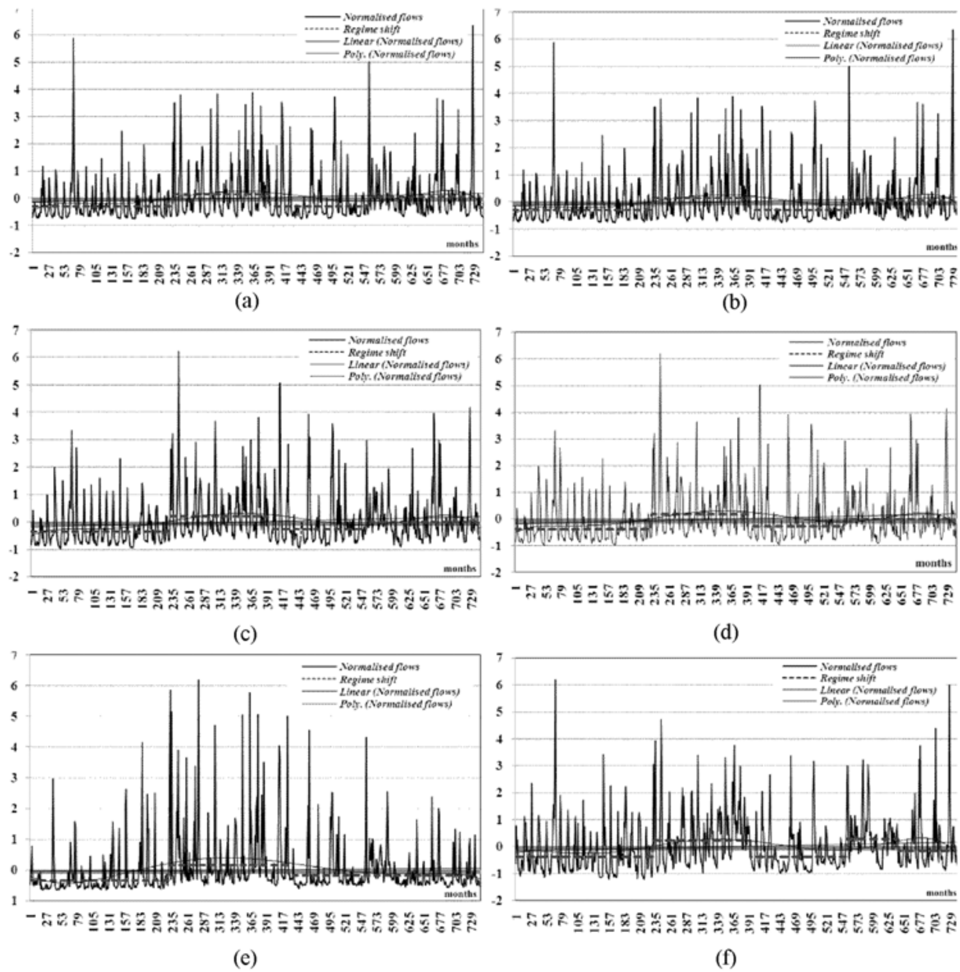
The hydrological area 3 has a hydrologic regime equally influenced by mountain climate and by ocean air advections due to the westerlies alternating with Eastern continental air movements (NAO phases). The domination of the influence of a particular type imposes the pluviometrical and hydrological characteristics of certain time intervals. The western influences give the dominant keynote to rainfall regime, by means of a slight pluvial-hydrometric surplus also supported by the characteristics of the mountain and high hills climatic altitudinal zone (1200, 800 m a.s.l.), which are primarily defined by an annual pluvial-hydric balance surplus. Western influences from the slopes facing E of the Carpathians are strongly modified by foehn processes. Continental influences can cross area 3 even in winter (e.g.: Nemira, local wind, a derivative of the Icy north wind generated by polar continental air movement), even if the cold, lens-shaped air masses do not exceed 1500 m in thickness.

The hydrological area 4 has a hydrological regime heavily affected by strong foehn effect on western air masses (a process which reaches its peak in April-May-June) and sometimes by retrograde cyclonic circulation. In winter, advections of eastern continental air masses (cold and dry) are very important, as they sometimes come in contact with the sub-Mediterranean air (warm and humid) generating frontal surfaces and cloud systems strongly developed which produce snow, later on affected by blizzard. All these events take place on the background of a predominantly mountainous climatic behavior in the west and center, and low plain in the east. Flow characteristics imposed by mountainous area extend in the rivers' lower sector located in a low-altitude plain area. The keynote is given by a slightly positive pluvial-hydric balance, but which in the studied interval was seriously affected by intense deforestation in the Carpathian area and in Vrancea Subcarpathians. Meanwhile, the torrentiality degree of precipitation is increased and in what concerns flow, the frequency of the extreme intervals is, also, increased (high and smaller-sized floods, small waters and even the drying out of some small rivers). Strong ventilation induced by foehn causes the pluvial-hydric excess in certain periods to be quickly consumed by very intense evapotranspiration processes.

The hydrological area 5 is a typical hilly plain (150-300 m a.s.l.) and plateau (250-550 m a.s.l.) area, under the determinant influence of continental air masses. Continental air masses are generators of contrasting weather conditions in terms of thermal, pluviometric and dynamic aspects. On the general background of poor rainfall, with the prevalence of droughty or low rainfall years, seasons, months and intervals (e.g.: in September-October 1982 it did not rain for 36 consecutive days at Botoşani, 33 days at Iaşi, 30 days at Dorohoi), certain intervals occur when, only during a rainfall episode, the amount of rain is comparable to the rainfall in a month (e.g.: 17-19 June 1985, when at Iaşi there were 193.8 mm of rainfall and at Răuseni 147.3 mm) or in a year (e.g.: in May 1970, at Strunga, 426.1 mm of rainfall water were recorded (Mihăilă, 2006)). Such intervals with pluviometric surplus produce hydrological bursts generating catastrophic flash floods and floods. +40ºC was recorded at Iaşi (27 July 1909) and -35ºC at the same station (1 February 1937 (Mihăilă, 2006)). In these cases, either evapotranspiration is very high and river flow rates reduce considerably or rivers are affected by intense frost phenomena that attenuate/cancel significantly/totally the flow. In this area the ultra-polar influence is the most striking.

Figure 8

INTER-MONTHLY EVOLUTION OF NORMALIZED FLOW RATES AT THE 45 GAUGES DURING 1950-2009, IN THE STUDIED HYDROLOGICAL AREAS. (a) HYDROLOGICAL AREA 1. (b) HYDROLOGICAL AREA 2. (c) HYDROLOGICAL AREA 3. (d) HYDROLOGICAL AREA 4. (e) HYDROLOGICAL AREA 5. (f) HYDROLOGICAL AREA 6



Own elaboration.

The hydrological area 6 represents only the Prut River regime downstream of Stânca-Costeşti Lake which determines a strong decrease in the Scandinavian-Baltic and mountain influences characteristic of the Prut river flow in the province 1, upstream of the lake. The received tributaries from the hydrologic area 5 and from Moldova (which probably has a similar regime as that of area 5) and the cross over Moldova Plateau required that Prut River have an apart, hybrid hydrological regime. Continental influences and the inherited mountainous regime equally describe the natural factors acting here.

These hydrological areas are smaller than the classical hydrological provinces used to characterize the studied region, as described by Ujvari (1972), and they partially overlap the last ones. Unlike Ujvari's characterization (1972), based on qualitative criteria such as slope position, elevation and atmospheric circulation and a dataset 3 times shorter than that used in the present study, our classification is solely based on mathematical and logical correlations.

The hydrological area 1 takes the characteristics of the Eastern Carpathian province (as it was described by Ujvari (1972)), overlapping its northern half. The hydrological area 3 overlaps the southern part of the Eastern Carpathian province and partly the Eastern part of the province located outside the Carpathian area (Peri-Carpathian province). The hydrological area 4 overlaps the Carpathian and Peri-Carpathian provinces at the Carpathian curvature. The hydrological areas 2, 5 and 6 cover together the rest of the Eastern Peri-Carpathian province; the currently available data covering a longer time interval allowed the separation of three hydrological areas instead of the old one, identified by Ujvari (1972).

Using flow rate data from each hydrological area, we obtained the historical evolution of an average theoretical flow for each hydrologic area separately. The average theoretic flow rate was obtained by averaging the standardized values of flow rates from each hydrologic area. In Figure 8 one can observe the differences between the theoretical average flow rates of the hydrological areas. The graphs showing the flow rate regime change were obtained according to the methodology described by Rodionov (2004), using a significance level of 0.1, Huber's weight of 1 standard deviation and an 132 months window to identify possible correlation with solar activity. These allow us to identify certain aspects related to the cyclical evolution of flow rates in 2cSP between 1950-2009, marked by two clear periods of growth and two of decline in flow rates. Currently, 2cSP is in a period of declining flow rates for each hydrological area, according to the data presented in Figure 8. Essential differences from the rest of the hydrological areas (especially for the long-term evolutionary trends) are shown by the areas 5 and 6, also visible in the regime shift of flow rates. The areas 1, 2, 3, 4 are highly influenced by the mountain climate in what concerns river flow. The area 5 is the only one which has no rivers with springs in the mountains. The area 6 has a similar behavior to the areas 1-4, but modified by the Stânca-Costeşti Lake, the plateau climate and eastern continental influences.

V. CONCLUSIONS

Due to considerable distances between the studied area and the energy reservoir of certain climate oscillations, the influence of the latter on 2cSP diminishes approximately directly proportional with the increase in distance. Thus, the influence of SO is smaller than the influence of NAO, which in turn is weaker than the influence of AO. Because the natural background of 2cSP acts as a noise source in the signal of the external factors influence on precipitation and flow, the studying of smaller, unitary areas from the viewpoint of climatic and hydrological elements is recommended and useful for obtaining stronger correlations between local and global.

VI. ACKNOWLEDGEMENTS

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