PRESENT ENVIRONMENT AND SUSTAINABLE DEVELOPMENT, VOL. 5, no. 1, 2011

LONG TERM VARIATION OF AIR TEMPERATURE IN THE SIRET CORRIDOR

Lucian Sfîcă[1]

Key words: air temperature, linear trend, cycles, periodicity, Siret Corridor.

Abstract. This study, supported by the analysis of data from meteorological stations located in the Siret Corridor, confirms the trend of the increase in air temperature in Romania. This increase is statistically proven by the analysis of a series of observations of mean air temperature in Roman, where the increase has been 0.88°C in the last century. Using the Fourier analysis, we could highlight the influence of several factors in the evolution of air temperature in the area studied. Amongst these, the most obvious ones were the biannual oscillation (which translates into alternating between 2 – 3 warm years with 2 – 3 colder years), the North Atlantic oscillation (7 – 8 years cycle), as well as lunar and solar cycles.

Introduction

Given the general concern over the global climatic change, the evolution of temperature is highly debated at the moment. This study analyses in great detail all components of the so called stochastic evolution of temperature, taking into consideration linear trends as well as cyclical evolution. The Siret Corridor, the region studied here, can be considered representative for the entire Moldova, given its morphographic and morphological characteristics.

We analysed the evolution of the temperature by means of its several key parameters from the 3 main meteorological stations located in the Siret Corridor: the mean annual temperature, the mean of the extreme temperatures, the thermic amplitude, and the number of summer and winter days.

1. Methodological aspects

In studying the evolution over the years of air temperature, the Siret Corridor benefits from already existing sound records of mean annual temperature observations carried out in Roman (1886-2005) and Bacău (1935-2005). For the 1956-2005 and 1961-2005 period, the other parameters were analysed based on the observations made in Bacău, Roman and Adjud.

---

[1] Teach. Assist. PhD., Alexandru Ioan Cuza Univeristy, Iaşi, sfical@yahoo.com.

As we mentioned before, this study looks at the multiannual evolution of this climatic component by emphasising not only the possible trends of evolution, but also the cyclical manifestations in the evolution of each of these climatic elements.

As regards the linear trends, these were analysed graphically, using the moving average and were validated through the use of linear regression. Also we have used the annual deviation from the mean annual temperature, and whilst the upper and lower deciles were applied to underline the increasing tendency of temperature in the recent period.

Besides evaluating the evolution trends, we have also attempted to identify the cyclical components which influence the climate. This was done using the spectral analysis (Fourier) and Statistica software, as the methodology of this analysis specifies (Patriche, 2009). The existence of these cycles can be intuitively estimated from the calculation of the moving average, but using the Fourier analysis adds a qualitative interpretation to them.

2. Linear trends

a. The mean air temperature. The multiannual evolution of mean air temperature was emphasised by the annual deviation from the mean air temperature of the observed period (fig.1). These indicate a clear trend of positive deviations after 1970. Besides this clear trend which is made obvious in the graph and is statistically significant, we can also take into account the existence of some variations manifested every decade and emphasised by 11 years moving average and also by 4th degree polynomial trend line. We can therefore, draw some conclusions:

- a first cold period stretches from the beginning of the observed period until the 1950s, when the lowest annual means from the entire observed period were recorded (6.1ºC in Roman in 1933, 6.3 ºC in 1940 and 6.7 ºC, and 6.9 ºC in Bacău – these recordings were made against a background of very low winter and summer monthly mean temperatures);
- this is followed by a relatively warmer period between 1945-1965, when the annual mean recordings went over 10 ºC in Bacău (1950, 1951) and settled at around 10°C in Roman (9.9 ºC in 1950, 9.5 ºC in 1951);
- a somewhat colder transition period between 1965-1985, which contained some very warm years, like 1975 (10.5 ºC in Adjud, 10.0 in Roman and Bacău);
- The current period of warm up is shown by the high number of successive years with positive deviations (1996-2005) and by the highest recorded values for the entire period of observation (11.3 ºC in Adjud in 1994, 10.8 in Bacău in 1994 and 1996, as well as 10.3 ºC in Roman in 2000). This warm-up period can be objectively illustrated by the fact that 6 of the 10 hottest years in record were

observed in Roman in this period and 7 of the 10 hottest years were recorded in Adjud and Bacău.

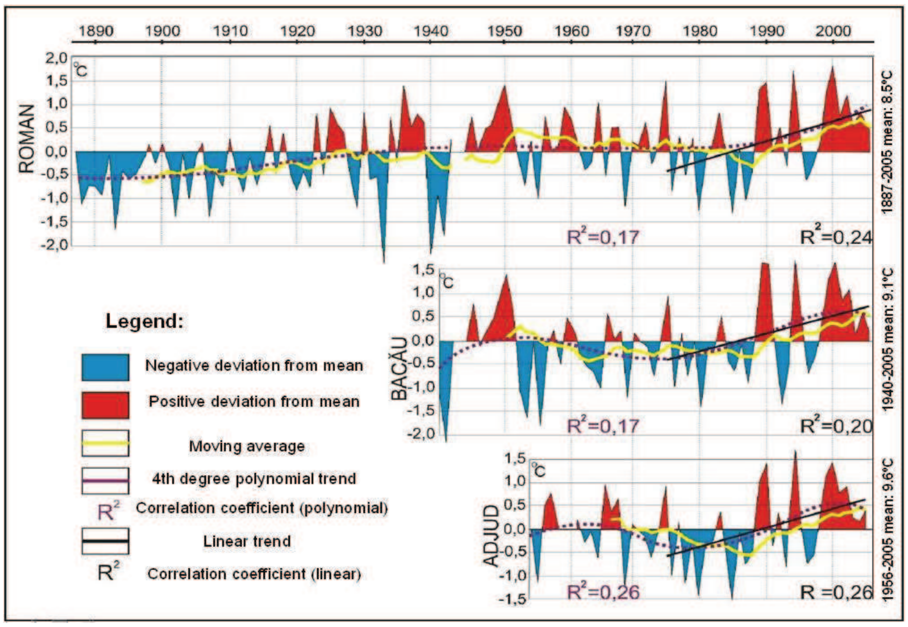

Fig. 1 – The multiannual evolution of annual mean temperature deviation from the mean in the Siret Corridor

Even if graphically, both the deviations and the mean value show a linear positive trend, very few of these are validated by the correlation coefficients. Thus, for the mean annual temperature, we can only observe a positive linear increase trend with app. 0.88°C/century in the meteorological station located in Roman. This trend explains app. 14% from the total deviation of this parameter for this period (fig.1). This value demonstrates that even at a regional level 'the warming up of the climatic system bears no doubt' (IPCC, 2007). In addition, this value is also a little over the mean value of the global increase of temperature, as estimated in the last report of the Intergovernmental Panel for Climate Change with 0.74ºC and is closer to the values shown by the increase of temperature at higher latitudes.

Another characteristic of the evolution of temperature is indicated by the trend of consecutiveness in groups of 2 – 3 years with positive and negative deviations, which shows the existence of a rhythmical appearance of 2 – 3 years. For the last decades we can observe the trend of groupings on larger intervals of years with positive thermal deviations.

b. The mean extreme temperatures. The monthly mean minimum and maximum temperatures are an important indicator in showing the evolution of air temperature at a large temporal scale because they balance out the exceptionally rare values recorded. These values can be the results of a particular or accidental synoptic condition in the dynamics of the atmosphere at continental scale.

Tab. 1 – The absolute frequency of 1990-2005 period in the upper and lower deciles of mean maximum temperature in the Siret Corridor (Ds-upper decile; Di-lower decile)

		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Total
Adjud	Ds	**3**	**3**	**3**	**2**	**3**	**3**	**2**	**2**	1	0	1	0	23
	Di	0	1	1	1	1	0	0	1	1	**1**	**3**	**4**	14
Bacău	Ds	**2**	**3**	**3**	**1**	**3**	**3**	**3**	**2**	1	**1**	0	1	23
	Di	0	1	1	1	1	0	0	0	1	0	**3**	**4**	12
Roman	Ds	**2**	**3**	**3**	**2**	**3**	**2**	**2**	**1**	1	0	1	1	20
	Di	0	1	1	1	1	0	0	0	**2**	0	**3**	**3**	10

The observed period: Adjud (1956-2005), Bacău (1940-2005) and Roman (1923-2005)

Tab. 2 - The absolute frequency of 1990-2005 period in the upper and lower deciles of mean minimum temperature in the Siret Corridor (Ds-upper decile; Di-lower decile)

		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Total
Adjud	Ds	**1**	**2**	**3**	**2**	2	**3**	**4**	**4**	**3**	0	1	1	26
	Di	0	1	1	1	2	0	1	0	1	0	**2**	**3**	12
Bacău	Ds	**2**	**3**	**3**	**2**	**2**	**2**	**4**	**2**	**2**	**1**	**2**	**1**	26
	Di	0	1	1	1	1	0	0	0	1	0	1	0	6
Roman	Ds	**1**	**3**	**2**	**3**	**2**	**2**	**3**	**4**	**3**	0	2	1	26
	Di	0	1	0	1	1	0	0	0	1	0	2	**2**	8

The observed period: Adjud (1956-2005), Bacău (1940-2005) and Roman (1923-2005)

Given this particularity of the mean extreme temperatures, I created a hierarchy of them for monthly intervals to bring forward arguments which support the conclusion made above about the trend of concentration of these higher values in the last years. Thus, I chose the 1990 – 2005 period, the last 16 years from the observations made at the 3 meteorological stations and I looked for each month at how many of the recordings made in these years were in the 10 highest readings (the upper decile) and in the 10 lowest readings (the lower decile). This analysis was created for both the mean of the maximum values (tab. 1) and of the minimum values (tab. 2) so that the result helps in understanding the impact of this global climatic change on the local conditions. If the climatic variables (in our case the mean extreme temperatures) would evolve constantly, with no positive or negative trends, the share of the last 16 years in the upper and lower deciles should be equal.

At an annual and cumulative level, we notice that the distribution of these values in the two deciles shows an obvious unbalance which makes us think of a significant impact of the climatic change on the region studied.

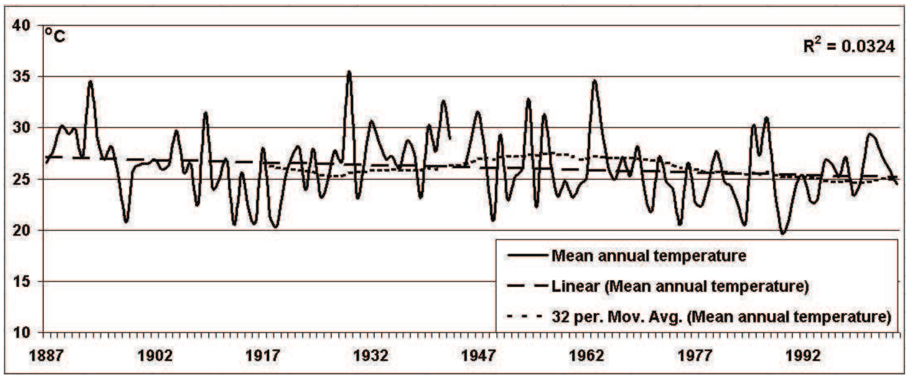

Fig. 2 – The annual thermic amplitude in Roman (1887-2005), stochastic evolution and trends

This is showed by the fact that for the mean maximum temperatures, the number of the months located in the upper decile is two times bigger than those located in the lower decile, and for the minimum mean temperatures, it is 3 times bigger. In addition, the number of the months situated in the upper decile is bigger for the minimum mean temperatures than for the mean maximum ones. These two aspects confirm that Siret Corridor is subjected to the regional and continental temperature trends (a significant increase of night and winter values, which can be noticed directly in the increase of the minimum temperatures). From these monthly values, one can notice also that the warming up is more significantly felt in January-August (the most in the summer months when there are almost no values for the lower decile for both parameters). In autumn, however, the minimum values are more frequently met. This is noticed even in December. This different behaviour of the autumn months (more precisely the last trimester of the year: October-December), could be explained by a higher inertia of the dynamic conditions of the atmosphere in this time of the year.

c. *The annual thermic amplitude* shows a decreasing trend for the region studied, given the overall increase of the temperatures in the winter months. The moving average help us notice that the annual mean amplitude was higher in the 1940 – 1960 (given the very cold winters of the 1941-1942 and very hot summers of the 1950 – 1951). These amplitude's of moving average indicate a decrease in the values of this parameter after 1975, which correlates with the period mentioned above (fig.2). Considering the importance of the mean annual thermic amplitude in defining the climate type in the temperate region, we can conclude on a decrease of the so called excessivity of climate manifestation, through the decrease of the thermic contrast between winter and summer. For example, the mean annual thermic amplitude in Roman for the period 1887-1955 was 26.7ºC, whilst in the interval 1956-2005, it was 25.3 ºC.

d. Number of days with typically characteristic temperatures. For this parameter, the linear trend, though statistically not proven, is in line with the increasing trend of the temperature in the last decades. For the winter season, the linear trend is not very visible, the moving average indicating a variation of 20 – 30 years cycle; the maximum values being registered in 1960 – 1965 and 1980 – 1985.

For the summer season, however, the increasing trend is far more visible on the graph, the moving average showing a continuous growth starting with 1975 – 1980.

3. **Climatic cycles and periodicity**

Using the Statistica software, I could identify with the help of periodigrams from Fourier analysis a series of characteristical features of the cyclical evolution of air temperature. These are shown below:

a. A = the periods of the identified cycles (harmonics) established with the help of correlation coefficients showed by the corelograms;

b. V = the variation (explained here in individual values) which shows in percentage the contribution of each harmonic to the total variation of the data series;

c. Δ = the amplitude of the cycle;

d. T (V) – the variation of the linear/polynomial trend;

e. r^2=the variation of the series adjusted taking into consideration the harmonics with a significant statistical contribution to the variation of the data series;

f. ES=standard error.

The results obtained after this synthesis for the 3 meteorological stations in the Siret Corridor are presented in the tables below (tab. 3- 6). I would like to mention that after analysing the periodigrams, I selected those cyclical components which, from a statistical point of view, explain the total variation of each climatic parameter mentioned.

Up to the present moment, in the Romanian literature on climatology authors made references to the impact of the 11 years cycle of the solar activity (the numbers of solar spots) on the amount of precipitation, concluding that a maximum solar activity correlates with a small amount of precipitation and in a relative 'calm' solar activity, increased amounts of precipitation are recorded (Rovența, Nicolau, 1975). Similarly, the role played by the lunar cycles on these meteorological parameters was researched (Isaia, 2002). Important contributions were made in the identification of the existing cyclicity of many climatic parametres from Iaşi and Vaslui (Patriche, 2005).

Tab. 3 – Statistical features of the multiannual evolution of air temperature in the Siret Corridor

	Adjud			Bacău			Roman		
	A	V	Δ	A	V	Δ	A	V	Δ
	5,6	14,4	2,9	8,0	10,1	2,6	59,0	10,6	2,9
	16,7	8,9	2,3	3,2	8,7	2,4	19,7	5,0	2,1
	7,2	7,4	2,1	10,7	7,8	2,3	3,2	4,6	1,9
	2,6	6,9	2,0	2,2	6,7	2,1	5,4	4,1	1,8
	3,1	6,1	1,9	21,3	5,6	1,9	7,9	3,6	1,7
				5,8	3,3	1,5	2,6	3,7	1,7
T(V)	-			-			-		
r^2	0,41			0,41			0,31		
ES	± 2,1			± 2,3			± 2,5		

Tab.4 – Statistical features of the multiannual evolution of thermic amplitude in the Siret Corridor

	Adjud			Bacău			Roman		
	A	V	Δ	A	V	Δ	A	V	Δ
	5,6	14,4	2,9	8,0	10,1	2,6	59,0	10,6	2,9
	16,7	8,9	2,3	3,2	8,7	2,4	19,7	5,0	2,1
	7,2	7,4	2,1	10,7	7,8	2,3	3,2	4,6	1,9
	2,6	6,9	2,0	2,2	6,7	2,1	5,4	4,1	1,8
	3,1	6,1	1,9	21,3	5,6	1,9	7,9	3,6	1,7
				5,8	3,3	1,5	2,6	3,7	1,7
T(V)	-			-			-		
r^2	0,41			0,41			0,31		
ES	± 2,1			± 2,3			± 2,5		

The Fourier analysis shows the causes responsible for this cyclicity. Overall, one can notice the existence of a great number of harmonics which explains only partially the variability of the studied parameters. These cyclicities have varied causes and many of them are still unexplained.

We may observe the omnipresence of the 2-3 years cycle, which plays an important part in the explanation of the total variation for the mean temperature in the Siret Corridor (4 – 17%). The importance of this cycle in the analysis of the temperature was discovered in North America in 1884 by W. Clayton and was named Biannual Oscillation (Finkl, 1987), having a period of 27 months. This oscillation is closely linked with the direction of the prevailing winds from the stratosphere in the equatorial regions between east and west. The general circulation of the atmosphere and its inertia determine a repositioning of this oscillation within the climatic elements, so that all of the harmonics positioned between 2.1 şi 2.9 can be linked with this oscillation. We believe that the Biannual Oscillation is responsible for the observed trend whereby the cold/warm years are grouped in alternating intervals of 2-3 successive years.

Tab. 5- Statistical features of the multiannual evolution of the number of winter days in the Siret Corridor

	Adjud			Bacău			Roman		
	A	V	Δ	A	V	Δ	A	V	Δ
	5,6	12,6	14,2	5,6	14,7	16,0	5,6	13,6	15,3
	16,7	9,0	12,1	8,3	12,3	14,7	8,3	7,7	11,8
	8,3	8,9	11,9	2,6	10,5	13,5	2,6	8,0	12,0
	2,6	8,7	11,8	16,7	7,3	11,4	16,7	6,3	10,7
	3,8	4,0	8,0	3,3	4,5	8,7	3,3	5,4	9,8
T(V)	-			-			-		
r^2	0,43			0,49			0,41		
ES	± 10,7			± 10,6			± 11,7		

Tab. 6 – Statistical features of the multiannual evolution of the number of summer days in the Siret Corridor

	Adjud			Bacău			Roman		
	A	V	Δ	A	V	Δ	A	V	Δ
	5,6	12,6	14,2	5,6	14,7	16,0	5,6	13,6	15,3
	16,7	9,0	12,1	8,3	12,3	14,7	8,3	7,7	11,8
	8,3	8,9	11,9	2,6	10,5	13,5	2,6	8,0	12,0
	2,6	8,7	11,8	16,7	7,3	11,4	16,7	6,3	10,7
	3,8	4,0	8,0	3,3	4,5	8,7	3,3	5,4	9,8
T(V)	-			-			-		
r^2	0,43			0,49			0,41		
ES	± 10,7			± 10,6			± 11,7		

The 3.3-4.5 years cycle has a less noticeable contribution in explaining the total variation – overall, under 5% - but it can be noticed in the evolution of most parameters analysed (tsb. 3 – 6). This cycle was also identified in the ENSO case (Burroughs, 2004), so that its very presence in most of the observations carried out can be seen as a local impact of the most ample and complex global atmospherical oscillation. The lunar cycles of 4 and 8 years may offer an explanation for the existence of the 3.3-4.5 years cycle, as they have the capacity of bringing changes in the characteristics of the Rossby's waves. In additions, the 16-18 years cycle,

which is mainly reflected in the number of summer and winter days, can be linked with the nutation lunar cycle of a 18.6 years (Camuffo, 2001).

Another identified cycled is that of 7-9 years which can also be found in the spectral analysis of the Index of North-Atlantic Oscillation (Werner, 1999). The impact of this cycle is far more obvious in the mean air temperature values (the 8.3 years cycle explains app. 7-12% from the total variation).

The solar activity represents – starting with the description of the solar spots by Heinrich Schwabe in 1843 – the most well-known example of cyclicity in the occurance of natural phenomina. The average period of this solar activity is of app. 11 years, but in reality it varies from 9 to 14 years, so that in the Fourier analysis, bearing in mind the inertia of transferring this signal through the atmosphere, we can associate to this activity the harmonics with values between 8-15 years. The impact of this 11 years cycle on the total variation can be noticed in the mean annual temperature (3-8%). This variation, which is added in the cycles identified in the multiannual evolution, is different from one climatic parameter to another. Thus, the identified cycles explain better the total variation in the number of summer and winter days (40-50%)

Conclusions

The evolution features of the climatic system belonging to the Siret Corridor cannot be extracted from the general characteristics from a regional and continental level. Some of them, however, can be identified with them.

One of them is the trend of mean annual temperature growth and the evolution (warming up) of other air temperature parameters. The growth of the temperature is more noticeable after 1970s, settling at 0.88 ºC in the last century, as per the recordings of the linear trend in Roman.

The causes of this temperature growth trend cannot be fully explained. There are no statistically proven trends of evolution for the other climatic elements which seem to be governed by cycles of evolution with origins of a complex nature, be it natural or man-made.

One cycle that can be mentionned as a certainty is the 2 years cycle of climatic elements which leads to the grouping of 2-3 years in a row with homogenous characteristics (hot, dry), followed by 2-3 years of oppposite chracteristics (cold, wet). Also worth mentioning is the cyclicity of the Atlantic influence (the 7-8 years period of the North Atlantic Oscillation), as well as the solar activity cycles (with a period of 11-13years).

References:

Burroughs, W.J. (2005), *Cycles and periodicities*, Encyclopedia of World Climatology, p.309-314, Springer.

Camuffo, D., (2001), *Lunar influences on climate, Earth, Moon and Planets*, 85-86: 99-113, Kluwer Academic Publishers, Springer.

Finnkl, C. W., Jnr., (1987), Rhodes W. Fairbridge: An Appreciation. In: RAMPINO, M. R.; SANDERS, J. E.; NEWMAN, W. S.; and KONIGSSON, L. K., 1987. Climate: History, Periodicity, and Predictability. Van Nostrand Reinhold USA, pps 446 to 471.

Garcia, N.O., Gimeno, L., De La Torre, L., Nieto, R., Anel, J., (2004), *North Atlantic Oscilation and precipitation in Galicia (Spain)*, Atmosfera, 25-32.

Isaia, I. (2002), Doua cicluri selenare şi impactul lor meteorologic, Lucrările Seminarului Geografic Dimitrie Cantemir, Iaşi.

Patriche C. V. (2005), *Podişul Central Moldovenesc dintre râurile Vaslui şi Stavnic-studiu de geografie fizică*, Ed. ,,Terra Nostra", Iaşi.

Patriche C. V. (2009), *Metode statistice aplicate în climatologie*, Ed. ,,Terra Nostra", Iaşi.

Rovența V., Nicolau T.(1975), *Ciclicitatea naturală - factor de bază în prognoza de lungă durată*, Stud. şi cercet., p. a II-a, Hidrolog., t. XLIV, I.M.H., Bucureşti.

Werner, A. (1999), Die *Nord-Atlantik Oscillazion und ihre Auswirkungen auf Europa*. Diplomarbeit, Inst. Meteorol. Geophys Univ. Frankfurt am Main.

*** *Climate Change, Synthesis report*, Core Writing Team, Pachauri, R.K. and Reisinger, A. (Eds.) IPCC, Geneva, Switzerland. pp 104.