

LONG-TERM VARIABILITY OF PRECIPITATION AND AIR TEMPERATURE IN CRISURI AND ARAD PLAINS

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Abstract

To show the secular fluctuations of precipitation and air temperature across the plains between the rivers Barcău and Mureș, we used the annual amounts of precipitation and annual average values of air temperature from weather stations which had the longest row of observation, on their operation period: Arad, during 1880-2012 (133 years) and Oradea, during 1901-2012 (112 years). So, the years as well as the rainy/dry, respectively the hot/cold decades were revealed. We pointed out what was the linear tendency of annual precipitation amounts and average annual temperatures during the secular period. The result was that the drought of the year 2000 exceeded that of the years 1946-1947. The driest year was 2000, and the wettest years were 1941 and 1889. The warmest year was 1934 and the coldest year was 1940. In Arad, during the secular period, precipitation decreased, while in Oradea they remained constant. The temperature remained constant in Arad, and in Oradea there was a very slight increase. The driest decade recorded at Arad station was 1921-1930, followed by 1941-1950 and the wettest decade was 1881-1890. The warmest decade in the plains was 2000-2009, followed by 1943-1952. The last years of the analyzed period, hot, were compared to some cold years (the period 1961-1990 or 1951-1990), and not thermally "normal" as believed, hence resulting exaggerate interpretations of some author's results.

Key words: precipitation, air temperature, long-term variability, tendency, decade, century.

INTRODUCTION

Long-term variability of the main meteorological elements – precipitation and air temperature – have aroused in recent years the interest of many researchers, both foreign (Bessemoulin et al., 2003; Litynski et al., 2003; Luterbacher, Xoplaki, 2003; Norrant, Douguedroit, 2003; Paul, Haidu, 2003; The Fourth Assessment Report of IPCC, 2007; Fratianni, Acquafredda, 2010; etc.) and Romanian (Ciulache, Cismaru, 2000; Boroneaș, Rîmbu, 2003; Măhăra, 2006; Mihăilă, 2006; Teodoreanu, 2007; Holobacă et al., 2008; Croitoru et al., 2008; Șerban, 2010; Croitoru et al., 2011; etc.), because of its consequences on the entire terrestrial climate, consequences that in turn affect the entire social, economic and biotic system. Hot or cold, rainy or dry decades had over time a great impact on human society and on the environment as a whole.

In this context, what we wish to set out, in this paper, is how the two climate elements have varied across the western plains of the country, over more than a century.

DATA AND METHODES

To observe how precipitation evolved during the century and get an overview of its fluctuations, the annual amounts of precipitation were analyzed from weather stations in the plains which had the longest row of observation, on their operation period: Arad, during 1880-2012 (133 years) and Oradea, during 1901-2012 (112 years). At the two stations, the

sequences of observations are not complete. So, the observations in the period 1910-1923 were missing at Arad station and also in Oradea several years in the interval 1903-1946.

To obtain the secular fluctuations of the annual average air temperature, available data rows from the same two stations were used. For Arad station we analyzed the period 1897-2012 (116 years), and for Oradea the period 1901-2012 (112 years). The two rows of data are not complete, they are missing a few years at the beginning of the analysis period.

For the studied intervals, the meteorological data were homogenized and they came from the archive of the National Meteorological Administration.

In the paper, the years as well as the rainy/dry, respectively the hot/cold decades were revealed. Each decade has received a thermal and pluviometric rating. The ratings have been given in accordance with Hellman's criterion (Fărcaș, 1988), the thresholds for decennial deviations being reduced to half of the annual, set by the climatologist Hellman (Table 1). We pointed out what was the linear tendency of annual precipitation amounts and average annual temperatures during the secular period.

Table 1

Pluviometric and thermal ratings of decades, according to Hellman's criterion
(Source: processing by Fărcaș, 1988)

Precipitation		Air temperature	
Decennial deviations (%)	Pluviometric rating	Decennial deviations (°C)	Thermal rating
over 12.5	Excessively rainy	over 2.5	Excessively hot
between 7.6 and 12.5	Very rainy	between 1.25 and 2.49	Very hot
between 5.1 and 7.5	Rainy	between 0.5 and 1.24	Hot
between 2.6 and 5.0	Moderately rainy	between 0.2 and 0.49	Warm
between -2.5 and 2.5%	Normal	between -0.19 and 0.19	Normal
between -2.6 and -5.0	Moderately dry	between -0.2 and -0.49	Cool
between -5.1 and -7.5	Dry	between -0.5 and -1.24	Cold
between -7.6 and -12.5	Very dry	between -1.25 and -2.49	Very cold
under -12.5%	Excessively dry	under -2.5	Excessively cold

RESULTS AND DISCUSSION

The secular variability of the annual precipitation amounts is shown in Figure 1. From the figure stands out the similar course of curves representing precipitation, meaning that across the plains between the rivers Barcău and Mureș, where the terrain is relatively uniform, precipitation largely depend on the general circulation of the atmosphere and less on relief. Air masses enter in the west of the country, undisturbed by orographic obstacles, after they crossed the quasi horizontal territory of the Pannonian Plain, so that they generate annual precipitation amounts with close values at the meteorological stations (Măhăra, 1977).

In the analyzed period, for over a century, precipitation ranged between 252.0 mm (the year 2000) and 893.3 mm (1889) in Arad and between 364.2 mm (2000) and 920.0 mm (1941) in Oradea. These were the driest, respectively the wettest years in the plain. The multiannual average amount of precipitation amounted to 614.5 mm in Oradea and 585.2 mm in Arad. The higher amount recorded at Oradea station was due to its location at the boundary between the plains and hills, where air masses are forced to escalate the landforms, generating higher rainfall (Măhăra, 1977).

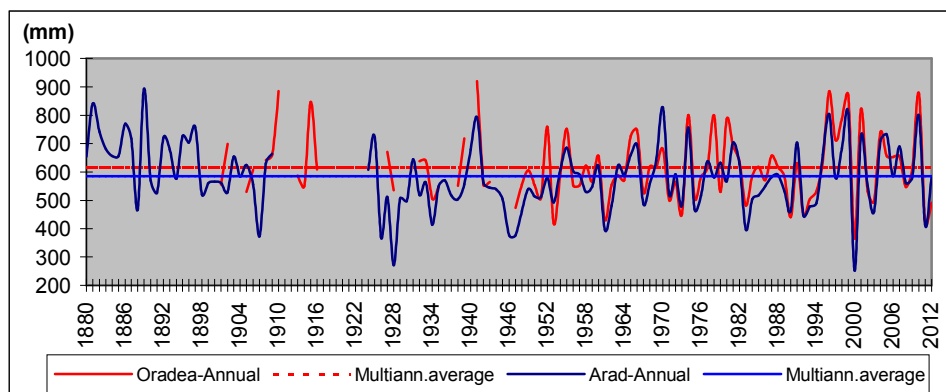


Fig. 1. Secular variations of the annual precipitation amounts compared to the multiannual average, at the stations Arad (1880-2012) and Oradea (1901-2012)

The figure shows that at both stations – from the pluviometric point of view – *the drought of the year 2000 exceeded that of the years 1946-1947* (when there were 375.4-375.6 mm in Arad and 473.3 mm in Oradea). Moreover, *in Arad the drought of the years 1946-1947 was exceeded even by that of 1928*, which was more intense (270.7 mm), *but also the years 1926 (368.7 mm) and 1907 (372.9 mm)*. However, the years 1946-1947 are at the middle of a dry decade – 1942-1953 – which made the drought of these years to be strongly felt by the population, while the drought of 2000 is included in a range of excessively rainy years – 1996-2001 – that have greatly diminished its effects due to the existence of a water surplus in soil from the previous years. The drought of year 1928 was also strongly felt in economic terms, because it was preceded by two dry years – 1926 and 1927 – of which 1926 was excessively dry.

The driest years (ordered by the annual minimum amounts) were: 2000, 1928, 1926, 1907, 1946, 1947, 1961, 1983, 2011, 1934, 1953, 1990, 1992. They totalled less than 450 mm precipitation.

The wettest years (ordered by the annual maximum amounts) were: 1941, 1889, 1910, 1996, 2010, 1999, 1915, 1881, 1970, 2001, 1974, which totalled over 800 mm precipitation.

The linear tendency of the annual precipitation amounts (Fig. 2) shows that *in Arad, within the secular period 1880 to 2012, the precipitation amounts were decreasing*. However, the downward trend is weak ($R^2 = 0.0186$) and it is determined by the existence of an interval of very rainy years at the beginning of the analyzed period (1881-1897), which gave the trend orientation. *In Oradea, during 1901-2012 the precipitation amounts remained constant*. Although the equation is negative, the correlation coefficient has a value close to zero, so that we consider the tendency constant.

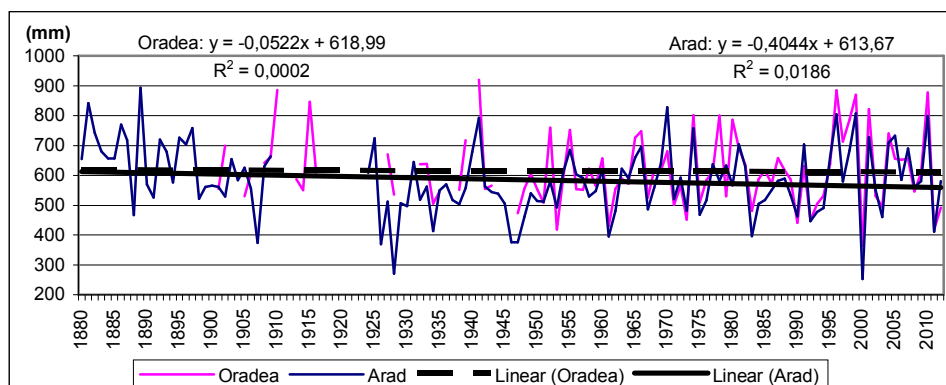


Fig. 2. The linear tendency of the annual precipitation amounts, at the stations Arad (1880-2012) and Oradea (1901-2012)

Since both rows of data containing intervals of years where data is missing and therefore, the trend can not be regarded as the best, Figure 3 has shows a tendency for the complete data row of the period 1924-2012, from Arad. In this period, precipitation has been *increasing*, but the increase is reduced. The tendency during 1927-2012 in Oradea – row that has some missing data – shows that there has been *increasing* rainfall, but the growth is weaker than before. The growth is due to the values of last years, when there were large amounts of precipitation (the interval 1996-2010) and lack of values in the first years of observation.

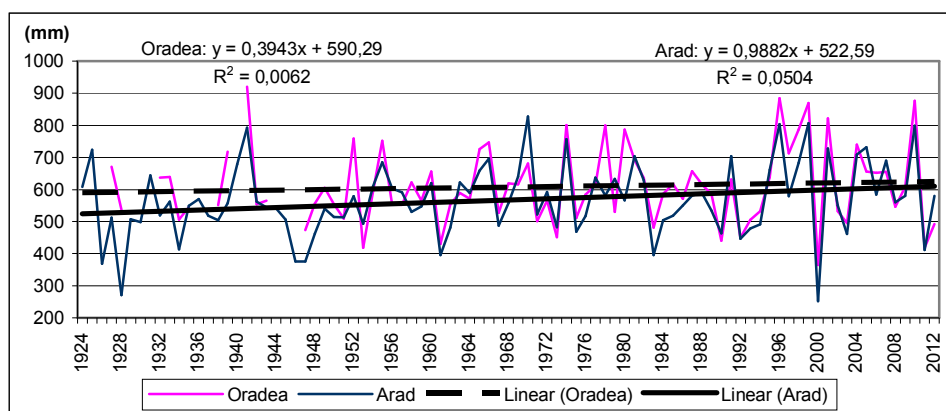


Fig. 3. The linear tendency of the annual precipitation amounts, at the stations Arad (1924-2012) and Oradea (1927-2012)

The secular fluctuations of the annual average air temperature from the weather stations Oradea and Arad are shown in Figure 4. The chart shows the similar course of the two curves, which means that both warm and cold periods were due to the same reasons related to the intensity of solar radiation and the general circulation of the atmosphere.

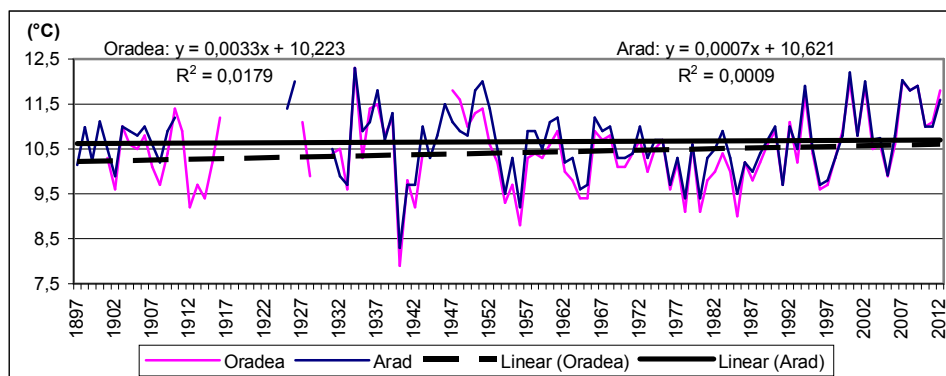


Fig. 4. Secular variations of the annual average air temperature and linear tendency, at the stations Arad (1897-2012) and Oradea (1901-2012)

During the analyzed secular period, air temperature varied between 8.3 °C (the year 1940) and 12.3 °C (1934) in Arad and between 7.9 °C (1940) and 12.3 °C (1934) in Oradea. The simultaneous generation of extreme values at the two stations stands out. They were the coldest, respectively the warmest years in the plain. The multiannual average temperature was 10.7 °C in Arad and 10.4 °C in Oradea, the higher temperature recorded in Arad being due to the lower latitude the station is located at.

The linear tendency of the annual average temperatures shows that *in the secular period analyzed, the temperature remained constant* in Arad and in Oradea there was a *very slight increase*. In Arad the equation is positive, which shows a very slight increase in annual values. However, since the correlation coefficient is very small, we consider the tendency constant.

Since both stations are missing a few years from the data row (between 1911 and 1924 in Arad, 1919-1926 in Oradea, 1929-1930 at both stations), Figure 5 represents the linear tendency for the period of time with a full data row. Thus, during 1931-2012, the air temperature showed a *slight increase* tendency at both stations.

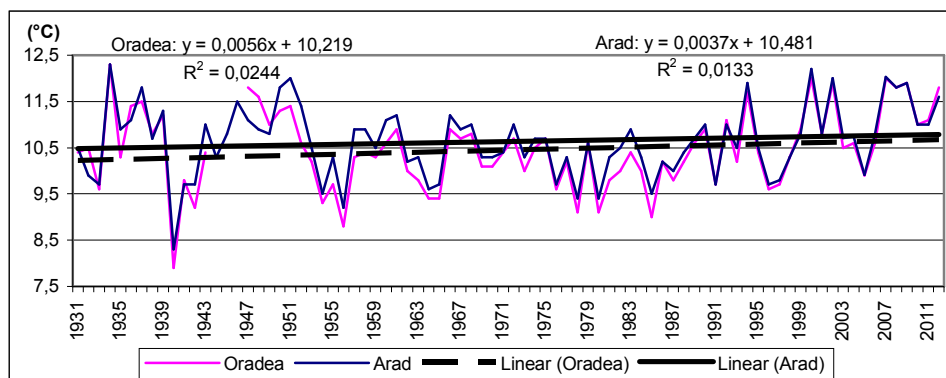


Fig. 5. The linear tendency of the annual average air temperature, at the stations Arad and Oradea (1931-2012)

Figure 6 shows decennial averages of the values of precipitation and temperature, in the 13 decades of the period 1881-2010. Each decade has received a thermal and

pluviometric rating, which was included in Table 2. In the table, some decades do not have these ratings due to missing data.

The result was that *the driest decade recorded at Arad station was 1921-1930*, followed by 1941-1950 (decennial average of precipitation was 500-520 mm). Moreover, the entire interval 1921-1950 was dry, including three decades. The decade 1981-1990 was dry and cool thermally. *The wettest decade was the first, 1881-1890* ("excessively rainy", with a very high decennial average of 700 mm). The first two decades and the last were rainy. All others were normal in terms of precipitation.

At Oradea station, only the first and last two decades of the analyzed period 1901-2010 were rainy, and the decades 1951-1960 and 1981-1990 were dry. All the others were normal in terms of precipitation. We can thus say that in the Arad Plain, the precipitation varies greatly from one decade to another, as a consequence of the Mediterranean influences, while in the north of Crisuri Plain the variation is weak, as a result of the climate with oceanic moderating influences.

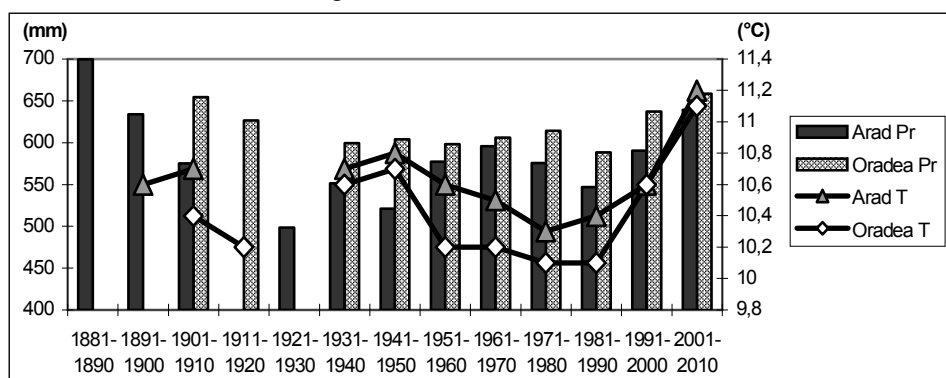


Fig. 6. Decennial averages of the precipitation amounts and air temperature, at the stations Arad (1881-2010) and Oradea (1901-2010)

Table 2
Thermal and pluviometric rating of decades, at the stations Arad (1881-2010) and Oradea (1901-2010)

STATION	Decade	1881-1890	1891-1900	1901-1910	1911-1920	1921-1930	1931-1940	1941-1950
Arad	Thermal rating	-	Normal	Normal	-	-	Normal	Normal
	Pluvio. rating	Excessively rainy	Very rainy	Normal	-	Excessively dry	Dry	Very dry
Oradea	Thermal rating	-	-	Normal	Cool	-	Warm	Warm
	Pluvio. rating	-	-	Rainy	Normal	-	Normal	Normal
STATION	Decade	1951-1960	1961-1970	1971-1980	1981-1990	1991-2000	2001-2010	
Arad	Thermal rating	Normal	Cool	Cool	Cool	Normal	Hot	
	Pluvio. rating	Normal	Normal	Normal	Dry	Normal	Very rainy	
Oradea	Thermal rating	Cool	Cool	Cool	Cool	Warm	Hot	
	Pluvio. rating	Moderately dry	Normal	Normal	Moderately dry	Moderately rainy	Rainy	

As regards the average temperature values, one hot decade was recorded at Arad station. *The warmest decade was the last, 2001-2010, which was hot and very rainy.* Opposite was *the decade 1941-1950, relatively warm and very dry* (even if it received the thermal rating "normal"). It is the second decade, as an average value of air temperature: 10.8°C. Decades 1961-1990 were cool, and all the others were thermally normal. In Oradea the temperature varied more than in Arad, the decades 1931-1950 and 1991-2010 being warm (with the hot decade 2001-2010), and the decade 1911-1920 and the interval 1951-1990, being cool.

This is the reason why climatologists in the country are concerned when discussing the problem of increasing air temperature in recent years. Most studies show a comparison of last years to the period 1961-1990 or 1951-1990. Therefore *the recent years, hot, were compared to some cold years, rather than thermally "normal" ones, as previously believed.*

In terms of the risk of both elements – temperature and precipitation – upon the socio-economic domain, we believe that *the greatest risk was the warm and dry decade 1941-1950* (the second decade as an average value of temperature, at both stations), when drought affected farm lands of the Western Plain and the heat made soil water loss through evaporation even greater. The combination "hot and rainy" typical for last decade is not as destructive as the previous one, at least in the field of agriculture. Always long lasting drought stronger makes its mark on the economy of a region than precipitation surplus.

The last interval, 2001-2010 – more specifically 1994-2012, since the reported temperature increase – was not the only hot interval of the analyzed period 1897-2012. Between 1934 and 1952 there were also many hot years. In fact, 1934 was the year with the highest values (12.3°C in Arad and Oradea) and exceeded the values of the years 2000, 2002, 2007, 2008, 2009, 2012. Moreover, *during 1934-1952 people had suffered a lot from the large air temperature variations* than during 1994-2012. Thus, from the very high values of the years 1934-1939 – when people had to endure excessive heat – extremely low values were recorded in 1940. Such a large temperature variation, from 1939 (11.3°C in Arad) to 1940 (8.3°C) – a difference of 3°C between the annual averages – caused *an extremely serious thermal stress*, not only among population, but also on animals and vegetation (in Oradea the difference between the two years amounted to 3.3°C). However, during the years 1994-2012, the transition from hot to cold years was not that great.

Therefore, we consider *the thermal situation of the years 1939-1940 as one of major risk for the population*, but also for other creatures. A similar situation could occur anytime in the future, which is why special attention should be paid to long-term weather forecasts.

As regards the warmest decade, it is the last, if we consider the decades starting or ending with round number years. But if we follow the exact time of producing the warmest years, then *the warmest decade was 2000-2009*, when its thermal average rose to 11.3°C in Arad and 11.2°C in Oradea. The second hot decade was *1943-1952*, when its thermal average amounted to 11.2°C at both stations.

CONCLUSIONS

The secular variability of the annual precipitation amounts highlights the fact that, from the pluviometric point of view, the drought of the year 2000 exceeded that of the years 1946-1947. The driest year was 2000, and the wettest years were 1941 and 1889. In Arad, during the secular period 1880-2012 precipitation decreased, while in Oradea, during the period 1901-2012 they remained constant.

The secular variability of the annual average air temperature shows that the warmest year was 1934 and the coldest year was 1940. During the analyzed secular period, the temperature remained constant in Arad, and in Oradea there was a very slight increase.

The driest decade recorded at Arad station was 1921-1930, followed by 1941-1950 and the wettest decade was 1881-1890. The warmest decade in the plains was 2000-2009, followed by 1943-1952. The last years of the analyzed period, hot, were compared to some cold years (the period 1961-1990 or 1951-1990), and not thermally "normal" as believed, hence resulting exaggerate interpretations of some author's results.

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