VARIABILITY OF AIR TEMPERATURE DURING THE SUMMER FROM THE PERIOD 1961-2021 IN THE SOUTHWEST OF ROMANIA, IN THE CONTEXT OF CLIMATE CHANGE

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ABSTRACT. **Variability of air temperature during summer from the period 1961-2021 in the southwest of Romania, in the context of climate change.** The periods of warming and cooling of the weather on Earth followed one another with great irregularity and caused significant variations in air temperature but allowed the existence of life and especially of the human species. In this paper we have analysed the variation of air temperature in Oltenia in the period 1961-2021. A number of our other works have analysed the variability of the climate in this part of Romania. After the warm period of 1945-1955, a gradual cooling of the weather followed in summers and during the period 1966-1984 (for 20 years). In summers, no thermal maximum of ≥40°C was registered. The period 2000-2021 (22 years) was the warmest of all the meteorological observations in Oltenia and many annual, monthly and daily climate records were surpassed. At the same time, during the analysed interval, the melting rate of the ice in the polar areas intensified a lot and exceptional thermal maxima were registered. The heat waves during the summers were more and more intense, more frequent and longer in duration. The paper is useful to all those interested in climate variability in Oltenia.

Keywords: hot summers, cool summers, drought, heat, heat waves, global warming.

1. INTRODUCTORY REMARKS

The year 2021 confirmed the rising trend of air temperature in recent decades. The frequency and intensity of dangerous meteorological phenomena (extreme temperatures, torrential rains generating floods, hail, storms, etc.) is increasing in Romania as well. In 2021, the most meteorological alerts were issued for dangerous phenomena at national level in the last 3 years. In the summer of 2021, the earliest red heat code (ANM) was issued. (https://newsenergy.ro/anm-tendinta-de-crestere-a-temperaturii-aerului-in-romania-a-continuat-in-2021/?fbclid=IwAR19ij8THVaboLjTG0gqUp2gMGb832F-

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0hROJOvyiZzzkKdrxc. At the same time, the summer of 2021 was a good counterexample for the statement that "if air pollution decreases, global warming will decrease or cease." The restrictions imposed in the three years (2020-2022) due to the Covid-19 Pandemic have diminished a large part of the industrial activities, and the air pollution has been reduced. As a result, very clear photographs of the Earth's surface have been taken from satellites in many parts of the world. The European Commission in Romania has published an image of Romania from space, captured with the help of the Sentinel-3 satellite. The satellite captured a spectacular image, which clearly shows the Carpathian arch, but also the Transylvanian Plateau, located in the centre, as well as the sub-Carpathian plateaus, but also the opening to the Black Sea. The image was taken in October 2021 with the help of the Sentinel-3 satellite (EU Copernicus). https://playtech.ro/2022/fotografia-cu-romania-din-satelit-ce-s-a-observat-este-total-surprinzator/

In 2019, a carbon dioxide concentration of 415 parts per million was set, much higher than other values ever reached in the last 800 thousand years. (https://www.digi24.ro/stiri/sci-tech/natura-si-mediu/atmosfera-mai-poluata-decat-se-credea-dioxidul-de-carbon-peste-valori-din-ultimii-800 -000-years-old-1129805). We also notice that this variation of the carbon dioxide concentration occurs starting with the fourth decimal (415 parts per million = 415X1000000-1 = 0.000415) and therefore with all the scientific estimates, without denying the influence of carbon dioxide in the atmosphere we consider that it is unlikely to have exceptional effects on global warming. In many of our works, we have analyzed the variability of the climate in southwestern Romania (Oltenia) (Marinică, I. 2006, Marinica I., Marinica Andreea Floriana 2016, 2019, 2020). Here is one of the main causes of global warming.

Causes of global warming

The rotation of the Earth around its axis is a complex process, and the axis of rotation has apparently small oscillations, which can produce significant climatic variations. The inclination angle of the Earth's axis with respect to the plane of the ecliptic is 66.5°. The precession movement of the Earth during the rotation around the Sun is the cause of the change of seasons on Earth. This angle of inclination is not fixed and has small variations[1] permanently. The accumulation of ice at the poles of the Earth changes this angle, reducing the inclination and increasing the angle with respect to the axis perpendicular to the plane of the ecliptic (obliquity, Fig. 1).

[1] Changing the obliquity of the Earth's axis (inclination) has effects on the magnitude of climate change. At higher bends, the seasons are more extreme, but at lower bends, they are milder. (https://www.scientia.ro/biografii/3140-milutin-milankovitch.html)

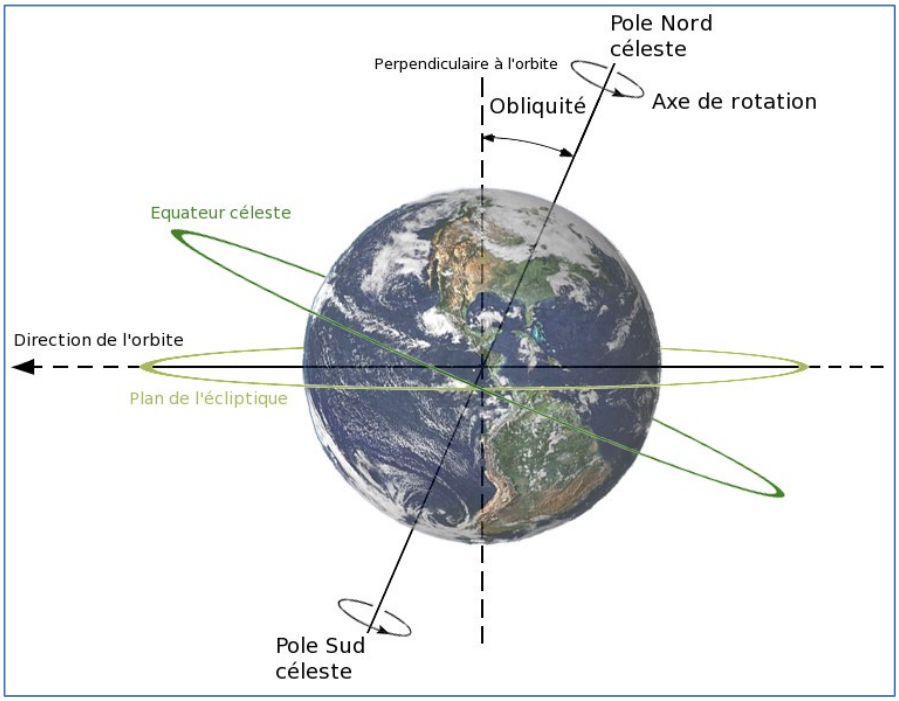

Fig. 1 The tilt angle of the Earth's axis (after https://ro.wikipedia.org/wiki/Ecliptic%C4%83)

As a result, the angle of incidence[2] (α, Fig. 2) of the sun's rays in the polar regions decreases (and only) causing warmer polar summers, the acceleration of the melting of the snow layer in the polar areas and very hot summers in the temperate regions. This oscillation of the Earth's axis was highlighted by the observations of the Inuit population in Alaska regarding the place of the sunrise and sunset (in this area of the polar circle the Sun rises and sets only once a year at the beginning and end of the polar day, which has an average duration of 6 months). Their observations have been confirmed as valid by NASA (the sun rises and sets in different places than it always did in the corresponding period) (https://goaravetisyan.ru/ro/sluchai-smeshcheniya-zemnoi-osi-prichiny-i-posledstviya-ugol/)

Earth axis's displacement situations, causes and consequences. (goaravetisyan.ru). During the hot polar summer, the melting of the ice mass accumulated here is accelerating. Melting part of the polar ice mass and redistributing the resulting water on the ground causes the obliquity to decrease,

[2] The variation limits of the angle of obliquity are between 22.1° and 24.5°. Currently the angle of obliquity is 23.5°, ie approximately the average value of its extremes.

and the angle of incidence of the sun's rays increases, as a result the polar days become colder and so the ice melts more slowly and accumulates in polar areas. This cycle of accumulation and melting of ice in the polar areas is repeated continuously (without having a perfect cyclicity). Thus hot or excessively hot summers occur periodically (periodicity which is irregular) (the oscillations of the Earth's rotation axis were also discussed by Milutin Milankovitch (1879 - 1958), in a theory, on which he worked all his life, theory published by NASA in 2000 (42 years after his death) on the website Earth Observatory, https://evz.ro/incalzirea-globala-nu-e-din-vina-omenirii-iata-explicatia-pe-care-elitele-o-ascund.html) Climate change caused by these variations is much stronger than the changes that the accumulation of carbon dioxide in the atmosphere can produce and which cannot produce quasi-cyclical variations in the appearance of excessively hot summers.

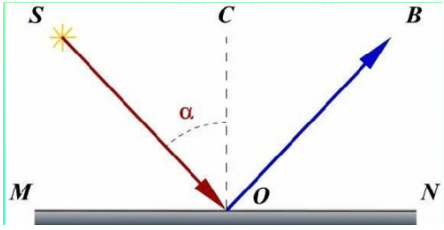

Fig. 2. The angle of incidence (α) of the sun's rays (after https://woodcar.ru/ro/laktaciya/kak-opredelit-ugol-padeniya-solnechnyh-luchei-geografiya-ugly-padeniya/)

Without questioning the influence of carbon dioxide accumulation on the atmosphere in terms of global warming, our opinion is that it cannot cause the quasi-periodic occurrence of excessively hot summers, which are due exclusively to the oscillations of the Earth's axis of rotation and other elements. Earth-Sun geometry, discussed by Milancovitch, which although small and difficult to highlight, produces important effects in global warming and cooling. (https://www.descopera.ro/dnews/9090888-rotatia-pamantului-a-fost-masurata-pentru-prima-data-gratie-unui-laser-ingropat-intr-un-buncar-subteran).

When the angle of obliquity increases, hot or excessively hot summers, warm years and warm winters are recorded, and when the angle of obliquity decreases, cool summers and frosty winters are recorded. These oscillations are natural and determined fundamentally by the main elements that characterize the Earth as a planet: the distance from the Sun, the obliquity of the axis of rotation, the distribution of continents and oceans, the rotational and precession movement, etc. which makes it unique in the universe known to humans. https://i2.wp.com/ studfiles.net/html/7651/383/html.

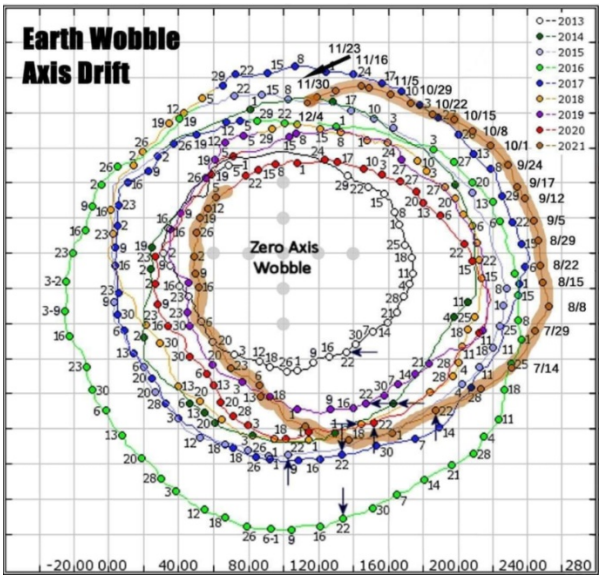

Fig. 3. *The shaking motion of the Earth's axis, relative to the vertical axis 0 (fixed position)* (Tilt and shake of the Earth December 4, 2021 (4.XII.2021 on the graph. on 16.XI.2021 on the chart) (https://www.facebook.com/photo.php?fbid=960076611572161&set=p.960076611572161&type=3).

It is currently estimated that the future of the Earth will be determined by a variety of factors, including increased brightness of the Sun, loss of heat from the centre of the Earth, disturbances of other bodies in the Solar System and biochemistry at the Earth's surface. Milankovich's theory predicts that the planet will continue to undergo cycles of glaciation due to the eccentricity of its orbit, the axial tilt, and the precession of the Earth's axis. (https://artsandculture.google.com/entity/m07k61br?hl=r, and https://en.wikipedia.org/wiki/Viitorul_P%C4%83m%C3%A2ntului)

2. DATA AND METHODS USED

To carry out the work we used data from the synoptic archives, existing synoptic maps on the Internet from the international weather forecasting centres, the ANM website, satellite information and information published in the written press. After processing the data and comparisons, the Hellmann Criterion[3] was

[3] Typically, comparisons, in most scientific papers, are made using multiannual averages of air temperature for the last 30 years. But the average for the last 30 years is a sliding average that also has an upward trend, as does the temperature. Therefore, the results of these comparisons are not very significant, indicating increases compared to what has been recorded in the last 30 years.

used, and as normal values the multiannual averages for the period 1901-1990 (last century) were taken into account. Experience working with the Hellmann criterion has shown that this is for climatology, which is Pythagoras' theorem for mathematics.

3. RESULTS AND ASSESSMENTS

3.1. Analysis of the seasonal averages of the air temperature, calculated for the entire Oltenia region (except the mountain area) for the period 1961-2021. In the 61 years studied, it was observed that the average summer seasonal temperature, calculated for the entire Oltenia region, was between 18.26°C in 1976, the coldest summer, with a deviation from the normal of -2.34°C, and 24.30°C in 2012 the hottest summer, classified according to the Hellmann criterion as very hot (FC). The variation of the seasonal averages of temperature was 6.04°C (Table 1).

There were 27 summers in the class of hot summers (44.26%) (which includes warm summers (CL), hot summers (C), very hot summers (FC) and excessively hot summers (EC)), 22 normal summers (N), ie 36.05% and 12 summers in the class of cold summers (which includes cool summers (RC), cold summers (R), very cold summers (FR) and exceptionally cold summers (ER)). Of these, only two summers were very hot (FC) - the summer of 2012 with a seasonal average of 24.30°C and a deviation from normal of 3.60°C (the highest seasonal deviation recorded so far - absolute climate record) and in the summer of 2007 with an annual average of 23.36°C and a deviation from normal of 2.66°C.

A single summer averaged ≥ 24°C - the summer of 2012. No excessively hot summers were recorded, indicating that seasonal deviations of more than 3.60°C are possible in the future.

The class of warmer-than-normal summers predominates, comprising 44.26% of the total number of summers, approaching 50.0%. The hottest 10 summers compared to normal (Table 2) were recorded since 2000, and the summer of 2000 by the maximum monthly values recorded, which surpassed some of the temperature records recorded so far marked a real turning point in climate change in southwestern Romania (Oltenia). Between 1964 and 1986, for 24 years, there was no hotter-than-normal summer. We mention that ***the winter of 1962-1963[4] was very cold (FR), the coldest winter in the same time period analysed and the only very cold one, with a seasonal average of -4.48°C and the deviation from normal of -3.52°C***.

[4] The winter of 1941-1942 was the last excessively cold (ER) winter recorded in the Northern Hemisphere so far, and after this winter, the rising trend of average seasonal temperatures continued.

Table 1. Seasonal averages of summer temperature (°C) and type of summers according to the Hellmann criterion[5], in the period 1961-2021 (average = annual average of summer air temperature, ΔT = deviation of the average seasonal temperature from normal, N = normal; R = cold, RC = cool, Cl = warm, C = hot, FC = very hot)

Year	Average	ΔT	Type	Year	Average	ΔT	Type	Year	Average	ΔT	Type
1961	20,53	-0,07	N	1982	20,36	-0,34	N	2003	**23,04**	2,34	**C**
1962	21,21	0,61	**CL**	1983	20,63	-0,07	N	2004	20,83	0,13	N
1963	21,94	1,34	**C**	1984	19,30	-1,40	**R**	2005	20,06	-0,64	**RC**
1964	20,86	0,26	N	1985	20,60	-0,10	N	2006	20,65	-0,05	N
1965	20,37	-0,23	N	1986	20,28	-0,42	N	2007	**23,36**	**2,66**	**FC**
1966	20,18	-0,42	N	1987	21,53	0,83	**CL**	2008	**22,26**	1,56	**C**
1967	20,76	0,16	N	1988	21,98	1,28	**C**	2009	21,86	1,16	**C**
1968	20,08	-0,52	N	1989	20,20	-0,50	N	2010	**22,50**	1,80	**C**
1969	19,48	-1,12	**R**	1990	20,94	0,24	N	2011	18,63	-2,07	**R**
1970	20,19	-0,41	N	1991	20,52	-0,18	N	2012	**24,30**	**3,60**	**FC**
1971	20,32	-0,28	N	1992	21,68	0,98	**CL**	2013	22,15	1,45	**C**
1972	21,07	0,47	N	1993	21,61	0,91	**CL**	2014	20,84	0,14	N
1973	19,84	-0,76	**RC**	1994	21,54	0,84	**CL**	2015	**22,65**	1,95	**C**
1974	20,28	-0,32	N	1995	21,18	0,48	N	2016	22,06	1,36	**C**
1975	19,87	-0,73	**RC**	1996	21,43	0,73	**CL**	2017	**23,09**	**2,39**	**C**
1976	***18,26***	-2,34	**R**	1997	20,19	-0,51	**RC**	2018	21,89	1,19	**C**
1977	20,17	-0,63	**RC**	1998	21,77	1,07	**C**	2019	**22,56**	1,86	**C**
1978	19,57	-1,23	**R**	1999	21,78	1,08	**C**	2020	21,80	1,10	**C**
1979	19,89	-0,91	**RC**	2000	**22,76**	**2,06**	**C**	2021	**22,91**	**2,21**	**C**
1980	19,84	-0,96	**RC**	2001	21,56	0,86	**CL**	***27 warm*** (CL, C, FC) (44,26%)			
1981	20,45	-0,35	N	2002	22,00	1,30	**C**	***12 cold and cool*** (19,67%)			

(Source: processed data)

This winter was followed by the hot summer (C) 1963 with a seasonal average of 21.94°C and a deviation from normal of 1.34°C. Thus, th***e year 1964 also marks a turning point in the evolution of air temperature***. The frequency of warmer-than-normal summers increased continuously, so in the period 1987-2021 the frequency was 71.42%, in the period 1992-2021 it was 76.67%, in the period 1998-2021 of 79.17%, and in the period 2007-2021 the frequency was 86.67%.

In contrast, in the class of colder than normal summers (which includes cool summers (RC) and cold summers (R)) there were 12 cold summers (19.67%) and very cold summers (FR), excessively cold summers (ER) were not registered.

[5] Hellmann criterion for seasonal and annual averages of air temperature: Δt≤-5.0 ° C = >excessively cold (ER); -4.9 ≤Δ -2.6°C = very cold (FR); -2.5 ≤Δ -1.1°C = cold (R); -1.0≤Δt≤ -0.6°C = >cool (RC); -0.5≤Δt≤ + 0.5°C = >normal (N); 0.6≤Δt≤1.0°C = >warm (CL); 1.1≤Δt≤ 2.5°C = >hot (C); 2.6 ≤Δ 4.9°C = > very hot (FC); Δt≥5.0°C = > excessively hot (EC).

Table 2. The warmest 10 summers and the coldest 10 summers and the type of summers according to the Hellmann criterion, in the period 1961-2021 (R = cold, RC = cool, Cl = warm, C = hot, FC = very hot)

No. crt.	The hottest 10 summers				The coldest 10 summers			
	Year	Average	Δt	CH	Year	Average	Δt	CH
1	2012	**24,30**	3,60	**FC**	1976	**18,26**	-2,34	**R**
2	2007	23,36	2,66	**FC**	2011	18,63	-2,07	**R**
3	2017	23,09	2,39	**C**	1984	19,30	-1,40	**R**
4	2003	23,04	2,34	**C**	1969	19,48	-1,12	**R**
5	2021	22,91	2,21	**C**	1978	19,57	-1,23	**R**
6	2000	22,76	2,06	**C**	1980	19,84	-0,96	**RC**
7	2015	22,65	1,95	**C**	1973	19,84	-0,76	**RC**
8	2019	22,56	1,86	**C**	1975	19,87	-0,73	**RC**
9	2010	22,50	1,80	**C**	1979	19,89	-0,91	**RC**
10	2008	22,26	1,56	**C**	2005	20,06	-0,64	**RC**

(Source: processed data)

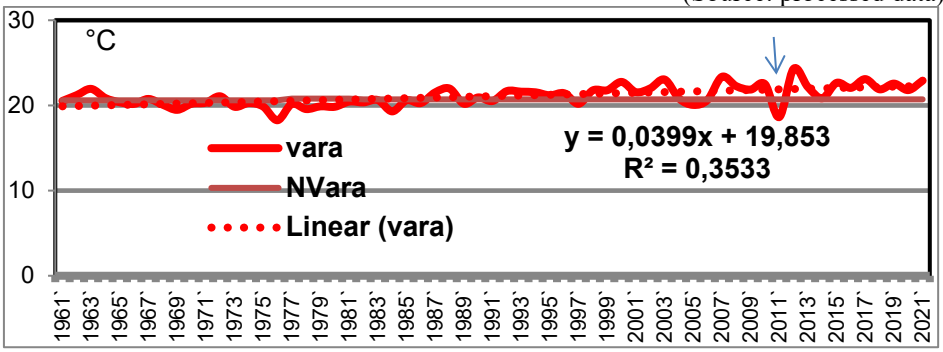

Fig. 4. The variation of the average seasonal air temperature for the summers from 1961-2021. (Source: processed data)

Given the above, it is clear that in the future, there will be a time when the climate will enter a cooling course and then there will be very cold (FR) and excessively cold (ER) summers, as recorded in past centuries. The cold summers (R) were only 5 (8.2% of the total) in the years: 1976, 2011, 1984, 1969 and 1978, and in the summer of 2011, it ranks second in ascending order of the lowest seasonal averages of temperature (18.63°C), with a deviation from normal of -2.07°C. This is due to climate variability in the northern hemisphere, which can cause cold summers to occur in a series of warmer-than-normal summers. The cool summers (RC) were only 7, (11.45% of the total): 1980, 1973, 1975, 1977, 1979, 1997, and 2005.

The graph of the variation of the average seasonal air temperature for the period 1961-2021 has a strong upward trend. (Fig. 4).

The average seasonal temperature for the whole period 1961-2021 and for the whole Oltenia region is 21.1°C and the deviation of 0.1°C, and according

to the Hellmann criterion it results that in the average the whole period was, normal thermally during the summers in as a whole, although many monthly and daily temperature records were broken.

3.2. Analysis of monthly average air temperatures in June, calculated for the entire Oltenia region (except the mountainous area) for the period 1961-2021

Although in June the day's length is maximum starting with June 21, most of the time it stays in the first half of it is cool and the rains are intense. As a result, most of the time the monthly maximum temperature is recorded in the second half of it. The highest monthly average calculated for the entire Oltenia region was 22.64°C, recorded in the hottest summer – 2012 (table 4), and its deviation from normal was 3.2°C, and according to the Hellmann criterion it was a warm month (C).

According to the Hellmann criterion[6], there were 25 warm June months (CL, C,) (40.98%), 7 months (11.48%) in the colder than normal classes (RC, R): and 29 months Monday June normal thermal (N) (47.54%) (Table 3 and 4). The predominance of thermally normal months is observed.

There was no very hot June for the whole region (FC) and no excessively hot (EC) (Table 3). There was only one cold June (R) in 1976 with an overall average of 17.28°C and a deviation from normal of -2.1°C. It has been 6 months in the cool (RC) class (1989, 1966, 2011, 1974, 1967 and 1969) which is actually close to normal. ***The variation of the monthly average temperature in June*** was 5.36°C. In June, many temperature records were broken for both the monthly and daily extremes at the weather stations, but also for the monthly average temperatures. Most of the warmer-than-normal months were recorded since 1998 (16 months), ie 66.67%, which shows that the year 1998 was a turning point in the evolution of air temperature in June.

[6] *Hellmann criterion* for monthly averages of air temperature: Δt≤ -10.0°C = >excessively cold (ER); -9.9 ≤Δt≤ -5.0°C = >very cold (FR); -4.9 - 2.0°C = (cool (R); -1.9 ≤Δt≤-1.0°C = >cool (RC); -0.9 tt + 0.9°C = normal (N); 1.0≤Δt≤ 1.9°C = >warm (CL); 2.0 ≤Δ 4.9°C = >hot (C); 5.0 ≤Δ 9.9°C = > very hot (HR); Δt≥10.0°C = > excessively hot (EC).

Table 3. Temperature averages recorded in June and the type of month according to the Hellmann criterion, between 1961-2021 (average = average temperature of the area for June, ΔT = deviation of the monthly average temperature from normal, N = normal; R = cold, RC = cool, Cl = warm, C = hot)

Year	Average	ΔT	Type	Year	Average	ΔT	Type	Year	Average	ΔT	Type
1961	20,13	0,8	**N**	1982	19,77	0,4	**N**	2003	22,49	3,1	**C**
1962	19,03	0,3	**N**	1983	19,41	-0,9	**N**	2004	19,36	-0,1	**N**
1963	20,46	1,1	**CL**	1984	18,49	-0,9	**N**	2005	18,93	-0,5	**N**
1964	21,49	2,2	**C**	1985	18,56	-0,9	**N**	2006	19,36	-0,1	**N**
1965	19,69	0,4	**N**	1986	19,43	0	**N**	2007	22,3	2,9	**C**
1966	18,05	-1,3	**RC**	1987	20,37	1	**CL**	2008	21,09	1,7	**CL**
1967	18,25	-1,1	**RC**	1988	19,6	0,2	**N**	2009	20,47	1,1	**CL**
1968	20,41	1,1	**CL**	1989	17,91	-1,5	**RC**	2010	20,78	1,4	**CL**
1969	18,32	-1	**RC**	1990	19,52	0,1	**N**	2011	18,02	-1,4	**RC**
1970	19,34	0	**N**	1991	20,26	0,8	**N**	2012	**22,64**	**3,2**	**C**
1971	18,66	-0,7	**N**	1992	19,25	-0,2	**N**	2013	20,54	1,1	**CL**
1972	21,24	1,9	**CL**	1993	20,57	1,2	**CL**	2014	19,32	-0,1	**N**
1973	19,09	-0,2	**N**	1994	20,08	0,7	**N**	2015	20,28	0,9	**N**
1974	18,19	-1,2	**RC**	1995	20,09	0,7	**N**	2016	21,47	2,1	**C**
1975	19,51	-0,4	**N**	1996	21,53	2,1	**C**	2017	22,54	3,1	**C**
1976	17,28	***-2,1***	**R**	1997	20,19	0,8	**N**	2018	20,88	1,5	**CL**
1977	19,05	-0,5	**N**	1998	20,74	1,3	**CL**	2019	21,81	2,4	**C**
1978	18,74	-0,8	**N**	1999	20,95	1,5	**CL**	2020	20,24	0,8	**N**
1979	20,84	1,3	**CL**	2000	21,9	2,5	**C**	2021	20,6	1,2	**CL**
1980	19,19	-0,3	**N**	2001	18,6	-0,8	**N**	*warm* (CL, C, FC) (40,98%)			
1981	20,87	1,3	**CL**	2002	21,86	2,5	**C**	*Cold or cool* (11,48%)			

(***Source: processed data***)

Table 4. The warmest 10 months of June and the coldest 10 months of June and the type of months according to the Hellmann criterion, between 1961-2021 (average = average air temperature in June, ΔT = deviation of the average monthly temperature from normal, N = normal; R = cold, RC = cool, Cl = warm, C = hot)

No. crt.	The hottest 10 June months				The coldest June months			
	Year	Average	Δt	CH	Year	Average	Δt	CH
1	2012	**22,64**	**3,2**	**C**	1976	**17,28**	***-2,1***	**R**
2	2017	22,54	3,1	**C**	1989	17,91	-1,5	**RC**
3	2003	22,49	3,1	**C**	1966	18,05	-1,3	**RC**
4	2007	22,3	2,9	**C**	2011	18,02	-1,4	**RC**
5	2000	21,90	2,5	**C**	1974	18,19	-1,2	**RC**
6	2002	21,86	2,5	**C**	1967	18,25	-1,1	**RC**
7	2019	21,81	2,4	**C**	1969	18,32	-1,0	**RC**
8	1996	21,53	2,1	**C**	1985	18,56	-0,9	**N**
9	1964	21,49	2,2	**C**	2001	18,60	-0,8	**N**
10	2016	21,47	2,1	**C**	1971	18,66	-0,7	**N**

(Source: processed data)

The absolute monthly temperature records for June were recorded especially after the year 2000 and we mention the highest: 41.3°C in Calafat on 26.VI.2007, 41.1°C in Băilești and Bechet and 39,7°C in Caracal on the same date, many of the records of June in Oltenia being records for the whole country.

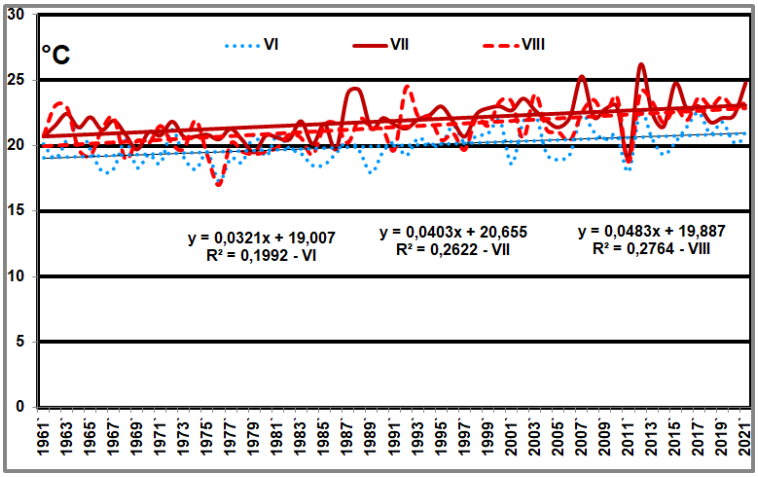

Fig. 5. The variation of the average monthly air temperatures for June, July and August from 1961-2021. (Source: processed data)

The variation graphs of the monthly average temperatures for the period 1961-2021 have a strong upward trend (Fig. 5), and for June, the growth coefficient was 0.0321, the lowest of all summer months.

The average air temperature for the whole Oltenia region and for the whole period 1961-2021, in June is 20.0°C, and its deviation from normal is

0.6°C, which according to the Hellman criterion results that on the whole, throughout June it was thermally normal.

3.3. Analysis of monthly averages of air temperature in July, calculated for the entire Oltenia region (except the mountainous area) for the period 1961-2021

The highest monthly average of July, calculated for the entire Oltenia region is 26.17°C, recorded in the hottest summer in 2012 (Table 5 and 6), and the deviation from this compared to normal was 4.7°C, 0.3°C lower than the limit of a very hot month. The lowest monthly average of July, calculated for the entire Oltenia region is 19.10°C recorded in the second coldest summer of 2011 (Table 5 and 6). Therefore, the variation of the average monthly temperature variation for the whole region was 7.07°C (the highest of the three summer months).

There were 17 warm July months (CL, C, FC, EC) (27.87%), 9 cold July months (RC, R, FR, ER) (14.76%) and 35 months July with normal temperature (N) (57.37%).

In the hottest month of summer, July, the normal thermal months predominated. The warmest months were recorded starting with 1987, 16 months (45.71%), and starting with 1999 there were 13 months (56.52%) and 9 warm July months (60.0%) since 2007, which shows that the warming weather in July has increased. In only 2 months of July (2007 and 2012), the monthly average air temperature for the entire region was ≥ 25.0°C and in just four months (2021, 2015, 1988 and 1987) it was ≥24.0°C.

Table 5. Average temperatures recorded in July and the type of month according to the Hellmann criterion, between 1961-2021 (average = average of July for the whole Oltenia region, ΔT = deviation of the monthly average temperature from normal, N = normal; R = cold, RC = cool, Cl = warm, C = hot, FC = very hot).

Year	Average	ΔT	Type	Year	Average	ΔT	Type	Year	Average	ΔT	Type
1961	20,70	-0,8	**N**	1982	20,47	-1,0	**RC**	2003	22,70	0,7	**N**
1962	21,54	0,1	**N**	1983	21,87	0,4	**N**	2004	21,90	0,4	**N**
1963	22,44	1,0	**CL**	1984	20,12	-1,4	**RC**	2005	21,40	-0,1	**N**
1964	21,39	0,1	**N**	1985	21,68	0,2	**N**	2006	22,20	0,7	**N**
1965	22,18	0,7	**N**	1986	19,75	-1,8	**RC**	2007	25,30	3,8	**C**
1966	21,21	-0,3	**N**	1987	24,00	2,5	**C**	2008	22,20	0,7	**N**
1967	21,91	0,4	**N**	1988	24,21	2,7	**C**	2009	22,80	1,3	**CL**
1968	20,86	-0,6	**N**	1989	21,31	-0,2	**N**	2010	23,00	1,5	**CL**
1969	19,72	-1,8	**RC**	1990	22,11	0,6	**N**	2011	19,10	***-2,4***	**R**
1970	21,04	-0,4	**N**	1991	21,60	0,1	**N**	2012	**26,17**	**4,7**	**C**
1971	20,79	-0,7	**N**	1992	21,31	-0,2	**N**	2013	22,53	1,0	**CL**
1972	21,84	0,4	**N**	1993	22.00	0,5	**N**	2014	21,47	0,0	**N**
1973	20,68	-0,8	**N**	1994	22,35	0,8	**N**	2015	24,77	3,3	**C**
1974	20,71	-0,8	**N**	1995	23,00	1,5	**CL**	2016	22,77	1,3	**CL**
1975	20,84	-0,8	**N**	1996	21,84	0,3	**N**	2017	23,01	1,5	**CL**
1976	20,49	-1,0	**RC**	1997	20,70	-0,8	**N**	2018	21,79	0,3	**N**
1977	21,29	-0,4	**N**	1998	22,41	0,9	**N**	2019	22,12	0,6	**N**
1978	20,42	-1,2	**RC**	1999	22,87	1,4	**CL**	2020	22,32	0,8	**N**
1979	19,49	-2,2	**R**	2000	23,00	1,5	**CL**	2021	24,79	3,3	**C**
1980	20,78	-0,9	**N**	2001	22,70	1,2	**CL**	*warm (*CL, C, FC) (27,87%)			
1981	20,61	-1,0	**RC**	2002	23,60	2,1	**C**	*Cold or cool* (14,76%)			

(***Source: processed data***)

Only two cold July months were recorded in 2011 and 1979 (Tables 5 and 6). ***The coldest month of July*** was in 2011 with an average of 19.1°C and the deviation from the normal of -2.4°C, located in the period with the warmest months (2007-2021), due to climate variability.

There was no very hot July (FC) on average for the whole region and no excessively hot (EC). Only in July 2012, on restricted areas, July was very hot (FC) – in Băilești, Caracal, Drăgășani, Apa Neagră, Polovragi and Rm. Vâlcea (40.0% of Oltenia) and other areas in southern Romania.

The highest temperature values recorded in July were: 44.3°C in Calafat on 24.VII.2007, 44.2°C in Bechet and 44.0°C in Băilești on the same date which are also absolute extremes of July for the whole country. Numerous climate records have been surpassed, both monthly and daily, and many of them have become country-wide records.

Table 6. The warmest 10 months of July and the coldest 10 months of July and the type of months according to the Hellmann criterion, between 1961-2021 (average = average air temperature in July for the whole Oltenia region, ΔT = deviation of the average monthly temperature normal, N = normal, R = cold, RC = cool, Cl = warm, C = warm)

No. crt.	The hottest 10 July months				The coldest July months			
	Year	Average	Δt	CH	Year	Average	Δt	CH
1	2012	**26,17**	**4,7**	**C**	2011	19,10	***-2,4***	**R**
2	2007	25,30	3,8	**C**	1979	19,49	-2,2	**R**
3	2021	24,79	3,3	**C**	1969	19,72	-1,8	**RC**
4	2015	24,77	3,3	**C**	1986	19,75	-1,8	**RC**
5	1988	24,21	2,7	**C**	1984	20,12	-1,4	**RC**
6	1987	24,00	2,5	**C**	1978	20,42	-1,2	**RC**
7	2002	23,60	2,1	**C**	1982	20,47	-1,0	**RC**
8	2017	23,01	1,5	**CL**	1976	20,49	-1,0	**RC**
9	2000	23,00	1,5	**CL**	1981	20,61	-1,0	**RC**
10	2010	23.00	1,5	**CL**	1973	20,68	-0,8	**N**

(***Source: processed data***)

The increasing coefficient of the air temperature in July, for the interval 1961-2021 is 0.0403 (Fig. 5), being the second largest in the summer months.

3.4. Analysis of monthly average air temperatures in August, calculated for the entire Oltenia region (except the mountainous area) for the period 1961-2021

During the analysed interval, in August there were 23 months of August in the warmer classes (CL, C, FC, EC) (37.7%), 17 months in the colder than normal classes (RC, R, FR , ER) (27.87%) and 21 in normal thermal classes (N) (34.43%), with warm ones predominating, being the only summer month in which warm weather (TC[7]) predominates, showing that the warming weather during the summer, usually in August, reaches its peak in this month. However,

[7] TC = all lines in the classes warmer than normal, TC = CL + C + FC + EC.

August is the first month of the year in which the monthly average air temperature presents the first decrease of 0.5°C, due to the gradual cooling of the weather after 15.VIII when the length of the night exceeds 10 hours.

The warmest August month according to the average air temperature in Oltenia was recorded in 1992, with an average monthly value of 24.48°C, and a deviation from normal of 3.4°C.

The maximum monthly temperature of August 1992, for Oltenia, was 37.8°C recorded at Calafat on 22.VII.1992. After the monthly thermal maxima, the warmest month of August in Oltenia, was August 1946 when at Strehaia (Mehedinți county) in 20.VIII ***was recorded the absolute thermal maximum for Oltenia of 43.5°C.*** In ***Romania, the absolute maximum temperature*** not only for August is 44.5°C[8] recorded on 10.VIII.1951 in Râmnicelu locality (Brăila county) at the Ion Sion agricultural farm, not upgraded so far. Values of 44.0°C were recorded on the same date (10.VIII.1951) at Amara-Slobozia on Ialomița and Valea Argovei on Mostiștea (both in Bărăgan). Other exceptional maximum temperature values for Oltenia are: 42.2°C in Calafat on 6.VIII.2017, 41.2°C in Bechet on 24 and 26.VIII.2012 and in Dăbuleni on 1 and 5.VIII.2021.

Table 7. Average temperatures recorded in August and the type of month according to the Hellmann criterion, between 1961-2021 (average = average air temperature in August for the whole Oltenia region, ΔT = deviation of the monthly average temperature from normal, Type = type of moon according to the Hellmann criterion, N = normal; R = cold, RC = cool, Cl = warm, C = hot)

Year	Average	ΔT	Type	Year	Average	ΔT	Type	Year	Average	ΔT	Type
1961	20,75	-0,3	**N**	1982	20,85	-0,2	**N**	2003	23,94	2,8	**C**
1962	23,06	2,1	**C**	1983	20,60	-0,5	**N**	2004	21,22	0,1	**N**
1963	22,92	1,9	**CL**	1984	19,30	-1,8	**RC**	2005	21,04	-1,1	**RC**
1964	19,71	-1,8	**RC**	1985	21,57	0,5	**N**	2006	20,39	-0,7	**N**
1965	19,24	-1,8	**RC**	1986	21,67	0,6	**N**	2007	22,51	1,4	**CL**
1966	21,26	0,3	**N**	1987	20,22	-0,9	**N**	2008	**23,51**	2,4	**C**
1967	22,13	1,1	**CL**	1988	22,08	1,0	**CL**	2009	22,31	1,2	**CL**
1968	18,96	-2,1	**R**	1989	21,38	-0,3	**N**	2010	**23,73**	2,6	**C**
1969	20,39	-1,2	**RC**	1990	21,21	-0,4	**N**	2011	18,77	-2,3	**R**
1970	20,19	-0,8	**N**	1991	19,71	-1,4	**RC**	2012	**24,09**	3,0	**C**
1971	21,51	0,5	**N**	1992	**24,48**	**3,4**	**C**	2013	**23,39**	2,3	**C**
1972	20,12	-0,9	**N**	1993	22,27	1,2	**CL**	2014	21,72	0,6	**N**
1973	19,76	-1,3	**RC**	1994	22,19	1,1	**CL**	2015	22,91	1,8	**CL**
1974	21,94	0,9	**N**	1995	20,44	-0,7	**N**	2016	21,95	0,9	**N**
1975	19,26	-1,8	**RC**	1996	20,93	-0,2	**N**	2017	**23,71**	2,6	**C**
1976	17,00	***-4,01***	**R**	1997	19,69	-1,4	**RC**	2018	22,99	1,9	**CL**
1977	20,17	-1,0	**RC**	1998	22,15	1,1	**CL**	2019	**23,74**	2,7	**C**
1978	19,54	-1,7	**RC**	1999	21,53	0,4	**N**	2020	22,84	1,7	**CL**
1979	19,34	-1,9	**RC**	2000	23,39	2,3	**C**	2021	**23,35**	2,3	**C**
1980	19,55	-1,7	**RC**	2001	23,38	2,3	**C**	*warm (*CL, C, FC) (37,7%)			
1981	19,87	-1,3	**RC**	2002	20,56	-0,5	**N**	*Cold or cool* (27,87%)			

(***Source: processed data***)

[8] The value of 44.5°C was accepted as valid (the station where it was measured being a private weather station of an agricultural farm) after many discussions considering that at other two nearby meteorological stations values of 44.0°C were recorded.

Nine of the warmest August 10 months were recorded since 2000 (Tables 7 and 8), and nine of the coldest August months were recorded between 1964 and 1997. We notice August 2011 the second coldest month of August in the 61 years, with the average for the entire Oltenia region of 18.77°C and the deviation of -2.3°C compared to normal. This is due to climate variability.

The analysis of temperature maximums and record data shows that the period 15.VII -15.VIII is generally the warmest interval of summer and, of course, of the year. Only two monthly averages were ≥24.0°C in 1992 and 2012. The average air temperature in August for the entire region and for the entire period 1961-2021 is 21.4°C, and its deviation from normal was 0.3°C, which according to the Hellmann criterion, leads us to the conclusion that in August, the entire analysed period (1961-2021) was thermally normal, although there were significant climatic variations. And in August, in the 61 years analysed, numerous monthly and daily thermal records were surpassed, except for the absolute thermal maximum for the whole of Romania.

Table 8. The warmest 10 months of August and the coldest 10 months of August and the type of months according to the Hellmann criterion, between 1961-2021 (ΔT = deviation of the average seasonal temperature from normal, N = normal; R = cold, RC = cool, Cl = warm, C = warm, FC = very warm)

No. crt.	The hottest 10 August months				The coldest August months			
	Year	Average	Δt	CH	Year	Average	Δt	CH
1	1992	24,48	3,40	**C**	1976	17,00	***-4,01***	**R**
2	2012	24,09	3,00	**C**	2011	18,77	-2,30	**R**
3	2003	23,94	2,80	**C**	1968	18,96	-2,10	**R**
4	2019	23,74	2,70	**C**	1965	19,24	-1,80	**RC**
5	2010	23,73	2,60	**C**	1975	19,26	-1,80	**RC**
6	2017	23,71	2,60	**C**	1984	19,30	-1,80	**RC**
7	2008	23,51	2,40	**C**	1979	19,34	-1,90	**RC**
8	2000	23,39	2,30	**C**	1980	19,55	-1,70	**RC**
9	2001	23,38	2,30	**C**	1997	19,69	-1,40	**RC**
10	2021	23,35	2,26	**C**	1964	19,71	-1,80	**RC**

(***Source: processed data***)

The graph of the variation of the average monthly temperature in August for all Oltenia has the fastest increasing trend of all summer months, equal to 0.0583 (Fig. 5).

3.4. Analysis of summer thermal maximums in Oltenia (except for the mountain area) for the period 1961-2021

The highest thermal maximum of summers for this interval was 44.3°C recorded in Calafat on 24.VII.2007, in the second warmest summer of the analysed interval.

There were 12 summers (19.67%) in which the maximum seasonal temperature for Oltenia was ≥40.0°C in the years: 2007 (44.3°C), 2000 (43.2°C), 2017 (42.2°C), 2012 (41.6°C), 1987 (41.6°C), 1985 (41.2°C), 2021 (41.1°C), 1988 (41.0°C), 2015 (40.9°C), 1993 (40.8°C), 1998 (40.8°C) and 1965 (40.2°C) (Table 8, 9 and 10).

The summers of 1993 and 1998 had the same thermal maximum of 40.8°C (table 9) recorded in August and July respectively, but the seasonal averages were 21.61°C for the summer of 1993 with a deviation from the normal of 0.91°C which was in the class of hot summers (CL), and in the summer of 1998 had a seasonal average of 21.77°C and a deviation of 1.07°C and was in the class of hot summers (C).

Table 9. Maximum temperatures recorded during the summer, between 1961-2021 (° C, Tmax = maximum seasonal temperature in summer, Station = weather stations: 482 = Calafat, 494 = Bechet, 465 = Băilești, 469 = Caracal, 450 = Craiova, 434 = Slatina, 340 = Tg. Jiu)

Year	Tmax	Date	Station	Year	Tmax	Date	Station	Year	Tmax	Date	Station
1961	38,2	11.VIII	482	1982	35,0	23.VII	395	2003	39,4	30.VIII	482
1962	38,1	2.VI	494	1983	36,6	20.VII	482	2004	39,2	10.VII	482
1963	39,6	16.VIII	469	1984	38,4	15.VII	482	2005	37,1	1.VIII	494
1964	35,4	21.VII	465	1985	41,2	31.VII	469	2006	39,4	28.VI	469
1965	40,2	26.VII	482	1986	36,0	19.VIII	494;369	2007	**44,3**	24.VII	482
1966	36,0	7.VII	465	1987	41,6	25.VII	469	2008	38,1	16.VIII	494
1967	38,4	11.VIII	494	1988	41,0	6.VII	494;465	2009	38,4	24.VII	410
1968	39,5	9.VII	482;465	1989	35,8	19.VIII	410	2010	39,1	28.VIII	494
1969	34,4	16.VIII	482	1990	36,8	1.VII	494	2011	38,3	24.VIII	482
1970	34,3	7.VIII	465	1991	36,8	1.VII	494	2012	41,6	15.VII	482
1971	37,6	8.VIII	450;340	1992	37,8	22.VIII	482	2013	39,8	29.VII	482
1972	39,3	16.VI	494	1993	40,8	25.VIII	494	2014	38,2	13;14.VIII	494
1973	38,8	18.VII	465	1994	39,5	11.VIII	482	2015	40,9	12.VIII	482
1974	38,4	14.VII	469	1995	35,4	3.VII	482	2016	38,0	1.VIII	494
1975	34,4	19.VII	465	1996	39,4	8.VII	494	2017	42,2	6.VIII	482
1976	**34,0**	21.VII	494	1997	37,6	5.VII	494	2018	36,3	26.VIII	494
1977	38,6	22.VIII	469	1998	40,8	2.VII	494	2019	38,2	8.VIII	494
1978	36,6	8.VIII	494	1999	39,0	10;20.VIII	482;494	2020	37,5	31.VIII	494
1979	37,5	1.VIII	494	2000	**43,2**	4.VII	482	2021	41,1	1.VIII	482
1980	39,4	10.VII	469	2001	39,2	10.VIII	465				
1981	37,5	4.VIII	482	2002	39,8	11;16.VII	482;494, 469				

(***Source: processed data***)

In 1998, temperatures of ≥40.0°C were recorded in the first days of July and in August and at several meteorological stations, and in 1993 only in the last part of August only at a single meteorological station and thermal maximums were frequent. ≥38.0°C. The thermal maximums of the summers were registered the most, at the meteorological stations from Câmpia Olteniei, as follows: at Bechet in 22 years, ie 36.06%, at Calafat in 19 years (31.14%), at Băilești and Caracal in 8 years (13.11%), in Craiova, Drăgășani and Tg. Jiu in one year (1.64%).

Therefore, in Dolj County, the most and highest seasonal maximum temperatures are recorded in summer (in 81.95% of years), and in some years, the Sahara of Oltenia doubles its surface (as it was in summer 2021). Only in 3 years (4.92%) the maximum thermal season for all Oltenia was registered in June: in 1962, 38.1°C at Bechet on 2.VI, 1972 with a maximum of 39.3°C on 16.VI at Bechet and in 2006, 39.4°C at Caracal on 28.VI. In July, the maximum thermal season was recorded in 28 years (45.9%), and the absolute thermal record of summers for Oltenia was recorded in July (44.3°C in Calafat on 24.VII.2007, which is also the record absolute temperature for July for Romania). In August, the maximum thermal season was recorded in 30 years (49.18%), and the thermal record of August for the period 1961-2021 in Oltenia, is 42.2°C in Calafat on 6.VIII, 2017. So in August most of the seasonal highs are recorded and so the summer heat intensifies (at least in the first half of the month).

Table 10. The 10 highest summer temperatures and the 10 lowest summers in the period 1961-2021 (°C, Tmax = maximum summer temperature in summer, Station = weather station, 482 = Calafat, 494 = Bechet, 465 = Băilești, 469 = Caracal, 450 = Craiova, 434 = Slatina, 340 = Tg. Jiu)

No. crt.	The highest 10 maxima				The lowest 10 maxima			
	Year	Tmax	Date	Station	Year	Tmax	Date	Station
1	2007	**44,3**	24.VII	482	1976	**34,0**	21.VII	494
2	2000	43,2	4.VII	482	1970	34,3	7.VIII	465
3	2017	42,2	6.VIII	482	1969	34,4	16.VIII	482
4	2012	41,6	15.VII	482	1975	34,4	19.VII	465
5	1987	41,6	25.VII	469	1982	35,0	23.VII	395
6	1985	41,2	31.VII	469	1964	35,4	21.VII	465
7	2021	41,1	1.VIII	482	1995	35,4	3.VII	482
8	1988	41,0	6.VII	494;465	1989	35,8	19.VIII	410
9	2015	40,9	12.VIII	482	1966	36,0	7.VII	465
10	1998	40,8	2.VII	494	1986	36,0	19.VIII	494;369

(***Source: processed data***)

The lowest temperature in the season was 34.0°C and was recorded in the coldest summer, 1976 on 21.VII at Bechet (Table 10). Ten of the lowest seasonal highs were recorded before 1995, when they were 36.0°C. During the summer of 1966-1984 (for 20 years), no thermal maximum of ≥40°C was recorded during the summer. The interval 2000-2021 (22 years) was the warmest of all the meteorological observations period in Oltenia.

However, for August some of the old thermal records remained unsurpassed: 43.5°C at Strehaia in 20.VIII.1946 (the absolute thermal record of August in Oltenia); 41.3°C in Drăgășani on 17.VIII.1952, 41.0°C in Băilești on 17.VIII.1952, 41.0°C in Craiova on 10.VIII.1922 and 40.5°C in Slatina in 1952.

CONCLUSIONS

During the summer in the period 1966-1984 (for 20 years), no thermal maximum of ≥40°C was recorded. The interval 2000-2021 (22 years) was the warmest of all the meteorological observations period in Oltenia.

In this analysed interval, in the south-west of Romania, the air temperature during the summers increased progressively, the increase being accentuated after 1995. Many monthly and daily records of temperature in all the summer months were surpassed. Summers often became hot with long periods of heat and heat waves accentuating the drought. The hottest area of Oltenia is the Oltenia Plain and especially Dolj County. The rising trend in air temperature is mainly due to the variability of the Earth's axis inclination which causes the cycles of melting and accumulation of ice in the polar regions and is not correlated with the increase in the concentration of carbon dioxide and other greenhouse gases, the summer 2021 being an example in this regard. If we consider that the excessively hot period from 1945-1955 was followed by a period of cooling between 1961 and 1986, followed by the warming of the weather, we can conclude that the interval analysed as a whole falls within a range of variability longer than about 66-70 years or even longer, with the peak of warming in the period 2000-2021 and the years to come. These long-term air temperature fluctuations correlate well with the oscillations of the Earth's tilt and melting cycles and the accumulation of ice in the polar areas analysed by Milankovitch, and **it is inevitable that a period of global climate cooling will inevitably occur in the future.**

REFERENCES

1. Marinică, I. (2006), *Fenomene climatice de risc în Oltenia,* Editura Autograf MJM, Craiova, 386 p. (Risk of Climatic Phenomena in Oltenia)
2. Marinică I., Marinică Andreea (2016), *Variabilitatea climatică în Oltenia şi schimbările climatice*, Editura Universitaria, Craiova, 306 p. (The Climate Variability in Oltenia and the Climatic Changes)
3. Marinică I, Marinică, Andreea (2019), C*onsiderations regarding the variability of earth-sun geometry and the climate variability in south-western Romania*, in ”Risks and Catastrophes” Journal, Year XIX, VOL. 25, No. 2/2019; pp 33-55.
4. Marinică I, Marinică, Andreea (2020), C*limate anomalies in south-west Romania in the spring of 2020, in the context of climate change*, in ”Risks and Catastrophes” Journal, Year XX, **27, 2**/2020, pp. 49-64.
5. ANM: Tendința de creștere a temperaturii aerului în România a continuat în 2021 - https://newsenergy.ro/anm-tendinta-de-crestere-a-temperaturii-aerului-in-romania-a-continuat-in-2021/ accessed on 5 July 2022

6. Atmosfera, mai poluată decât se credea https://www.digi24.ro/stiri/sci-tech/natura-si-mediu/atmosfera-mai-poluata-decat-se-credea-dioxidul-de-carbon-peste-valori-din-ultimii-800-000-de-ani-1129805 accessed on 4 July 2022
7. Cazuri de deplasare a axei pământului, cauze și consecințe https://goara vetisyan.ru/ro/sluchai-smeshcheniya-zemnoi-osi-prichiny-i-posledstviya-ugol/ accessed on 3 July 2022.
8. „Încălzirea globală" https://evz.ro/incalzirea-globala-nu-e-din-vina-omenirii-iata-explicatia-pe-care-elitele-o-ascund.html accessed on 1 July 2022
9. Cum se determină unghiul de incidență al geografiei razelor solare. Incidența și umbrirea la soare - https://woodcar.ru/ro/laktaciya/kak-opredelit-ugol-padeniya-solnechnyh-luchei-geografiya-ugly-padeniya/ accessed on 5 July 2022.