CANICULAR SUMMER 2021 IN SOUTH-WEST ROMANIA IN THE CONTEXT OF CLIMATE CHANGE

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Abstract. ***Canicular summer 2021 in south-west Romania in the context of climate change.*** The particularly hot summer of 2021 occurred after the third Mediterranean winter registered in Oltenia. Although the winter was warm, being the third warmest winter in descending order of the seasonal average, the spring of 2021 was cold not only in Oltenia, even in the Northern Hemisphere being considered one of the coldest springs. This weather remained until 15.VI, then on 22.VI began the first heat wave of summer 2021. During the summer of 2021 there were 6 heat waves that had several peaks. (19) with intensities frequently exceeding 38,0°C. The summer maximum temperature was 41.1°C recorded on 1.VIII.2021 in Calafat. The drought and heat wave were intense, and the total duration of the heat waves was 50 days (54.3% of summer days). The particularly hot summer of 2021 was recorded in atypical conditions with neutral Southern Oscillation (ENSO). All spring crops were severely affected. The paper analyses the climatic conditions in the summer of 2021 in Oltenia and climate variability.

Keywords: drought, heat, heat waves, climate risks.

1. INTRODUCTION

After the warm winters, in some years, excessively hot summers followed. A summer is ***excessively hot*** if during the heat waves the maximum temperatures are ≥ 40.0°C or according to the Hellmann Criterion the deviation of the seasonal average is ≥5.0°C. In the last 14 years, the frequency of excessively hot summers in Oltenia has increased as follows:

- ***the summer of 2007*** was excessively hot and occurred after the warmest winter in the history of Romania's climate (winter 2006-2007). On 24.VII.2007, the absolute thermal maxima of July were registered for the whole country, not only for Oltenia: 44.0°C in Băilești, 44.2°C in Bechet and Dr. Tr Severin, and 44.3°C at Calafat.

- in ***the summer of 2012***, the thermal maxima of 41.6°C was registered

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at Calafat on 15.VII.2012. This winter occurred after the frosty winter of 2011-2012, when between 27.I and 19.II.2012, the temperature minima decreased to values between -28.9°C (1.II.2012) at Băileşti and Ob. Lotrului, and -21.7°C at Dr. Tr. Severin on 9.II.2012.

- ***in summer of 2015***, thermal maxima of 40.3°C were recorded at Zimnicea on 30.VII.2015, 40.7°C at Giurgiu also on 30.VII.2015 and 40.9°C at Calafat on 12.VIII.2015 (contested by ANM, on the grounds that the synoptic situations do not correspond to such a temperature value, but which remained valid in the database). This summer came after the warm winter of 2014-2015 with a seasonal average of 1.21°C and a deviation from normal of 2.16°C.

- ***in the summer of 2017***, the thermal maxima of 42.2°C was registered at Calafat on 6.VIII.2017. Summer came after the 2016-2017 normal thermal winter, with the seasonal average of -1.35°C and the deviation from the normal of -0.95°C.

- ***in the summer of 2021***, thermal maxima of 40.0°C were registered at Calafat on 29.VII. 2021 and 41.1°C also at Calafat on 1.VIII.2021. The excessively hot summer of 2021 occurred after the third Mediterranean winter 2020-2021.

The Mediterranean winters registered in Oltenia were: ***2006-2007*** with the seasonal average of 3.44°C and the deviation of 4,39°C, ***2019-2020*** with the seasonal average of 2.89°C and the deviation of 3.84°C, and ***2020-2021*** with a seasonal average of 2.55°C and a deviation from normal of 3.5°C.

It should be noted that, so far (2021), ***there has not been an excessively hot winter*** in the sense of the Hellmann Criterion (with the deviation of the seasonal average from normal ≥5.0°C). ***Very warm winters***, according to the Hellmann Criterion (with deviations of the seasonal averages between 2.6°C and 4.9°C), in the last 60 years, have been only 5: ***1982-1983*** with an average of 2.05°C and deviation from normal of 3.0°C; ***2000-2001*** with the seasonal average of 1.7°C and deviation from the seasonal average from normal of 2.65°C; and ***the three mentioned above as Mediterranean winters.***

We can also mention that ***no summer season was excessively hot*** in the sense of the Hellmann Criterion.

In 2021, the evolution of the climate was alternating, so ***after the warm Mediterranean winter of 2020-2021***, followed a ***cold spring***, which was even in Europe ***one of the coldest springs recorded on the continent***. The colder than normal weather was extended until 15.VI.2021, and starting with 22.VI.2021 followed the first heat wave of this summer. Excessively hot weather dominated the entire period of 22.VI-17.IX.2021, with thermal maxima that frequently exceeded 34.0°C. Excessively hot weather has been recorded in much of Europe, Asia and the Americas, and in some areas of the Northern Hemisphere it has begun since April. Thus globally, in ***April 2021***, "The global surface temperature of April 2021 had values with 0.79°C (1.42°F) above the average of the twentieth century to values of 20°C (13.7°F) higher. ***April 2021 was the***

ninth warmest month of April since 2013. April 2021 was the 45th consecutive month, with temperatures above the average of the last century. Lower-than-average temperatures have been observed on much of the world's land and ocean surfaces, with the most notable warm anomalies in eastern Canada, southern South America, northwest and southwest Asia and southern Africa, where temperatures have been at least 2.5°C (4.5°F) above average. April's record temperatures were present in areas of southern South America, southern Africa, the Middle East and the Pacific and Atlantic oceans" (NOAA/NCEI Global Analysis accessed May 16, 2021).

The summer of 2021 was particularly hot over most of the Northern Hemisphere, and the heat waves were interrupted by short periods (1/3 days) in which the temperature dropped slightly, then the hot weather returned. In the summer of 2021, the term ***heat dome*** was widely used, and although this term is not a specialized one, it was used mainly by Anglo-Saxon journalists to characterize very intense and persistent episodes of heat waves (HotNews.ro Roxana Bojariu). Such a dome behaves like a "mountain of heat" that has stood for a long time in the Balkans, and Romania was situated on its edge. In Greece, Albania and Macedonia the maximum temperatures exceeded +43.0°C, and in Romania the maximums were ≥40.0°C. Such an anticyclone thermobaric formation has the property of self-sustaining by the continuous air heating from the superheated and dry terrestrial surface. In Italy, Spain and Greece, the old thermal records of July and August have been surpassed. (https://romania. shafaqna.com/EN/AL/757534). Between 25.VII and 8.VIII.2021 above the Northern Hemisphere were present simultaneously 6 heat domes in different areas. As a result, numerous vegetation fires broke out in Greece and many other countries, and teams of firefighters from Romania and Greece's neighbouring countries twice participated in extinguishing the fires. Analysis of the causes of these fires revealed that ***most were caused by human action***.

The sixth IPCC Report on Climate Change, called by the press "red code for humanity" seems to be made at a political command due to conclusions that are difficult to sustain. The continuous presentation of weather forecasts in alarmist style as well as press articles that amplify and overestimate the effects of climate change, increased the stress of the population, which coupled with that caused by the Covid-19 Pandemic led to ***a new mental illness called climate anxiety***. (https://www.digi24.ro/stiri/externe/mapamond/anxietatea-climatica-o-problema-noua-pentru-multi-tineri-din-lume-ei-nu-mai-vor-sa-aiba-copii -because-the-future-is-worrying-1668081). The multitude of alarmist presentations on the issue of climate change has led to their presentation as an "***eco-climate apocalypse***" and the emergence of the idea that it is ***necessary to reduce the Earth's population*** to 65% of the current number. The idea is dangerous because the reduction of the Earth's population can slow down a lot

or even stop the technological and scientific development of the world and in the end it will even lead to widespread poverty. (https://www.activenews.ro/externe/Un-document-semnat-de-11.000-oameni-de-stiinta-cere-REDUCEREA-populatiei-pentru-a-salva-planeta-de-%E2%80%9Climate–changes-Unrestricted-access-to-methods-of-%-E2%080%9-Family-planning-and-decrease-of-women's-fertility-158683.) Without contesting caused mainly by global warming, we recall ***a fundamental truth in our world***, coming from the mists of time, which has never been denied before***: "as long as Earth will last, there will be no end to day and night, heat and cold, seeding and ploughing" (Genesis), a statement that guarantees the maintenance of the Earth's climate within limits that make possible the existence of life on Earth and especially of man, he being the only one who sows and reaps.*** The statement is supported by the rotational motion of the Earth and the precession. The precession movement is what determines ***the alternation of the polar day with the polar night which in turn is the main cooling mechanism of the Earth's Atmosphere***. Global warming has led to the rapid growth of the Earth's population, due to the increasing amount of food, and the population in turn has rapidly and greatly amplified scientific research and technology development. The Earth's climate is the one that regulates the population and not the other way around, and it has always been so. According to some data, ***in the next 2000 years (2001-4000), the Earth's climate will be warmer than in the last 2000 years (0-2000)***. Certainly there will be large climatic fluctuations and there will be intervals of climate cooling, and cosmic, geological causes and anthropogenic impact will play an important role. We will further analyse the particularly hot summer of 2021 and its synoptic causes. The paper is part of an extensive series of analyses of climate variability and climate change in Oltenia (Marinica, I. 2006; Marinica I., Marinica Andreea Floriana, 2016, 2019, 2020).

2. DATA AND METHODS USED

For this paper we used synoptic maps existent on the internet from the international weather forecast centres, the ANM site, satellite information and information published on the written press.

3. RESULTS AND ASSESSMENTS

3.1. Climate characteristics of June 2021

The thermal regime of June 2021. *The monthly averages of the air temperature* were between 16.2°C at Voineasa and 22.9°C, and their deviations from normal were between 0.2°C at Slatina and 3.1°C to Apa Neagră. According to the Hellmann Criterion, June was thermally normal (N) in most of the Oltenia

Plain, in the Getic Piedmont at Slatina, at the southern limit of the Oltenia Hills (Tg. Logrești) and in the Voineasa Intra-mountain Depression and in the rest of Oltenia (almost 50% of the area) was warm (CL). On a small area in the Subcarpathian Depression the Apa Neagră it was warm (C) (Table 1). The monthly average air temperature calculated for the entire region was 20.6°C, and its deviation from normal was 1.2°C, which shows that on average June 2021 was warm (CL) for the entire region. The monthly minims of air temperature were recorded, most in the first three days and were between 4.8°C in Voineasa and 10.2°C in Bechet, and their average for the entire region was 8.2°C. The monthly maximum air temperatures were recorded mostly in the period 23-25.VI and were between 32.3°C at Polovragi on 23.VI.2021 and 39.3°C at Calafat on 25.VI.2021. The maximum temperature values quickly passed the heat threshold (32.0°C) starting with 22.VI. The heat wave (temperatures ≥ 35.0°C) was registered starting with 23.VI and predominant in the low altitude area of Oltenia. ***The first heat wave of summer 2021 was registered between 22.VI and 1.VII, lasting 10 days***, being the first signal that summer will be hot. The early weather warming at the beginning of summer is a good prognostic signal of the warm weather that followed throughout the summer. The average monthly highs for the entire region were 35.8°C. *The monthly minima of soil surface temperature* were recorded mostly in the first three days, between 4.2°C at Polovragi on 25.VI.2021 and 11.5°C at Bechet on 3.VI.2021, and their average for the entire region of 7.9°C.

Table 1. *Air temperature regime in Oltenia and minimum and maximum surface temperature values in June 2021* (Hm = station altitude, Δ = MN = deviation from the normal average temperature in June, CH = Hellmann Criterion, NVI = average temperatures for June calculated for the period 1901-1990 - normal; MVI = average temperatures in June 2021)

Meteorological Station	Hm	NVI	MVI	Δ = M-N	CH	Tmax air		Tmin air		Tmax soil		Tmin soil	
						(°C)	Date	(°C)	Date	(°C)	Date	(°C)	Date
Dr. Tr .Severin	77	20,7	22,6	1,9	CL	37,5	25	9,8	15	41,6	24	8,0	3
Calafat	66	21,0	22,9	1,9	CL	39,3	25	9,1	2	44,5	25	7,1	1
Bechet	65	21,3	21,7	0,4	N	38,0	30	10,2	2	49,5	10	**11,5**	**3**
Bailesti	56	21,1	22,0	0,9	N	37,8	25	9,1	2	46,3	29	8,3	2
Caracal	112	20,8	21,4	0,6	N	37,0	25	10,1	2	47,0	24	10,8	15
Craiova	190	20,6	21,1	0,5	N	36,0	25	9,2	2	48,2	25	7,8	14
Slatina	165	20,5	20,7	*0,2*	N	36,2	24	8,3	3	42,3	30	9,1	3
Bacleș	309	19,0	20,7	1,7	CL	34,7	24	8,3	15	-	-	-	-
Tg. Logresti	262	18,8	19,4	0,6	N	34,6	24	6,0	3	57,8	30	6,2	15
Dragasani	280	19,4	20,6	1,2	CL	35,1	25	8,9	2	39,3	30	10,3	3
Apa Neagra	250	16,6	19,7	3,1	C	34,6	23	5,8	15	*40,7*	25	7,6	3
Tg. Jiu	210	19,4	20,8	1,4	CL	35,5	23	8,0	5	60,6	30	4,5	11
Polovragi	546	17,7	19,0	1,3	CL	*32,3*	23	7,2	15	56,1	29	***4,2***	***15***
Rm. Valcea	243	19,0	20,3	1,3	CL	34,4	23	7,8	3	62,3	25	6,8	3
Voineasa	587	15,3	*16,2*	0,9	N	33,4	24	*4,8*	5	-	-	-	-
Parang	1585	-	-	-	-	-	-	-	-	-	-	-	-
Average Oltenia	-	19,4	20,6	1,2	CL	35,76	-	8,2	-	48,9	-	7,9	-
Ob. Lotrului	1404	10,8	12,0	1,2	CL	28,2	25	0,1	5	-	-	-	-

(Source: data processed from the ANM Archive)

The maximum temperatures at the soil surface were mostly recorded in the period 24-30.VI and were between 40.7°C at Apa Neagră on 25.VI.2021 and 62.3°C at Rm. Vâlcea, and their average for the whole region was 48.9°C.

The variation graphs of the parameters that characterize the air temperature in June (daily highs, daily averages and daily lows) had strongly increasing linear trends, and the daily highs had the fastest growth, with a significant growth coefficient of 0.4398 (Fig. 1).

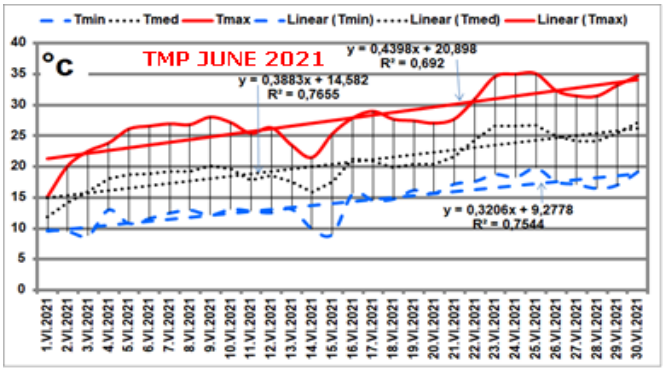

Fig. 1. Variation of air temperature averages, daily maximums, daily averages and daily minimums calculated for the entire Oltenia region in June 2021. (Source: data processed from the ANM Archive).

Rainfall in June

The monthly precipitation quantities were between 22.5 l/m^2 at Dr. Tr. Severin and 140.3 l/m^2 at Voineasa, and the percentage deviations from normal were between -69.0% at Dr. Tr. Severin and 56.9% at Caracal. June 2021 was excessively dry (ES) in western and south-western Oltenia at Dr. Tr. Severin and Calafat; very dry (FS) in the Oltenia Plain at Băilești, in the Getic Piedmont at Slatina, in the Olt Corridor at Drăgășani and Rm. Vâlcea, and in the Subcarpathian Depressions at Apa Neagră and Polovragi; dry (S) at Tg. Jiu; slightly dry (PS) in the mountain area at Parâng; rainy (P) in the Oltenia Plain at Bechet and Craiova and in the Mehedinți Hills at Bâcleș; very rainy (FP) in the Voineasa Intra-Mountain Depression and excessively rainy (EP) in the Romanați Plain at Caracal. The average monthly quantities calculated for the entire region was 69.5 l/m^2, and its deviation from the normal of -17.4% which shows that June was on average slightly dry (PS) for the entire Oltenia region. In June, small rainfall amounts below 5.0 l/m^2 predominated. Only in 2 days (11 and 18.VI) were recorded precipitation amounts ≥20.0 l/m^2, and in the intra-montane depression Voineasa in the dates of 25, 26 and 30.VI.

At the end of June, for the autumn wheat crop, the water soil supply on the profile of 0-100 cm was within satisfactory limits, close to optimal and optimal, on most agricultural areas. The moisture reserve in the corn crop, on the soil depth 0-100 cm, showed satisfactory values up to close to optimal and

optimal. The water content of the soil was low (moderate pedological drought), isolated in southern Oltenia. The rather good situation was due to the precipitation during the winter and spring (ANM).

Table 2. *Amounts of rainfall recorded in summer of 2021 (Σ), compared to normal values (N for the period 1901-1990), deviation (Δ%) and the type of rainfall according to the Hellmann Criterion (CH).*

Meteorological Station	Hm	June 2021				July 2021				August 2021			
		ΣVI	N	Δ%	**CH**	**ΣVII**	N	Δ%	**CH**	**ΣVIII**	N	Δ%	**CH**
Dr. Tr. Severin	77	***22,5***	72,5	***-69,0***	**ES**	**19,3**	49,3	-60,9	**ES**	**17,2**	38,2	-55,0	**ES**
Calafat	66	**29,8**	65,6	-54,6	**ES**	**36,2**	45,6	-20,6	**S**	***2,6***	35,6	-92,7	**ES**
Bechet	65	**75,4**	62,3	21,0	**P**	**30,6**	46,6	-34,3	**FS**	**15,2**	37,9	-59,9	**ES**
Băilești	56	**35,7**	66,5	-46,3	**FS**	**35,0**	45,0	-22,2	**S**	**3,6**	39,0	-90,8	**ES**
Caracal	112	**115,6**	73,7	***56,9***	**EP**	**47,2**	53,8	***-12,3***	**PS**	**9,0**	39,9	-77,4	**ES**
Craiova	190	**85,8**	71,2	20,5	**P**	**17,4**	51,4	-66,1	**ES**	**12,3**	42,1	-70,8	**ES**
Slatina	165	**45,6**	80,6	-43,4	**FS**	**41,4**	57,5	-28,0	**S**	**7,2**	46,8	-84,6	**ES**
Băcleș	309	**87,8**	72,0	21,9	**P**	**39,7**	47,1	-15,7	**PS**	**8,1**	*33,4*	-75,7	**ES**
Tg. Logrești	262	**77,4**	72,3	7,1	**N**	***15,4***	49,5	-68,9	**ES**	**42,4**	43,6	-2,8	**N**
Drăgășani	280	**59,8**	87,6	-31,7	**FS**	**37,4**	51,6	-27,5	**S**	**32,8**	46,4	-29,3	**S**
Apa Neagră	250	**51,7**	99,2	-47,9	**FS**	**19,5**	72,7	***-73,2***	**ES**	**59,9**	60,1	-0,3	**N**
Tg. Jiu	210	**71,8**	93,0	-22,8	**S**	**22,2**	61,9	-64,1	**ES**	**28,3**	64,3	-56,0	**ES**
Polovragi	546	**64,4**	112,3	-42,7	**FS**	**40,8**	88,9	-54,1	**ES**	**31,4**	76,5	-59,0	**ES**
Rm. Vâlcea	243	**43,5**	86,9	-49,9	**FS**	**53,5**	98,0	-45,4	**FS**	**54,6**	69,4	-21,3	**S**
Voineasa	587	**140,3**	106,7	31,5	**FP**	***60,9***	88,6	-31,3	**FS**	***98,9***	72,8	35,9	**FP**
Parâng	1585	**105,6**	124,1	-14,9	**PS**	**75,6**	132,1	-42,8	**FS**	**94,2**	90,6	4,0	**N**
Average Oltenia	-	69,5	84,2	-17,4	**PS**	37,0	65,0	-43,0	**FS**	32,4	52,3	-38,1	**FS**
Ob. Lotrului	1404	**89,9**				**95,6**				**32,8**			

(Source: data processed from the ANM Archive)

3.2. Climate characteristics of July 2021

The thermal regime of July 2021

The monthly averages of the air temperature were between 19.6°C at Voineasa and 27.2°C at Dr. Tr. Severin, and their deviations from normal were between 2.5°C at Bechet and Voineasa and 4,2°C at Dr. Tr. Severin (Table 3). According to the Hellmann Criterion, July was hot (C) throughout Oltenia. ***The average monthly air temperature*** for the entire Oltenia region was 24.8°C, and its deviation from normal was 3.3°C, which according to the Hellmann Criterion shows that July was a warm month (C) for the entire Oltenia region.

Table 3. *The air temperature regime in Oltenia and the minimum and maximum temperature values at the ground surface in July 2021* (Hm = station altitude, Δ = MN = deviation from normal of the average temperature in July, CH = Hellmann Criterion, NVII = average temperatures for July calculated for the period 1901-1990 - normal; MVII = average temperatures in July 2021)

Meteorological Station	Hm	NVII	MVII	Δ= M-N	CH	Tmax air		Tmin air		Tmax soil		Tmin soil	
						(°C)	Date	(°C)	Date	(°C)	Date	(°C)	Date
Dr.Tr .Severin	77	23,0	***27,2***	***4,2***	**C**	37,8	29	14,3	4	43,3	29	14,7	5
Calafat	66	23,2	26,7	3,5	**C**	38,4	28	14,1	5	45,7	29;31	***17,6***	3
Bechet	65	23,0	25,5	***2,5***	**C**	***40,0***	29	15,1	5	48,9	7	16,2	5
Bailesti	56	22,8	26,1	3,3	**C**	39,5	28	12,9	5	50,1	12	16,1	5
Caracal	112	22,9	25,8	2,9	**C**	38,5	28	12,8	5	51,2	22	14,0	22
Craiova	190	22,3	25,7	3,4	**C**	37,8	28	10,1	3	51,5	29	13,1	4
Slatina	165	22,0	25,3	3,3	**C**	35,1	28	10,9	3	44,1	31	15,1	4
Bacleș	309	21,3	24,8	3,5	**C**	37,1	28	11,1	3;4	-	-	-	-

Tg. Logresti	262	20,7	23,9	3,2	C	39,4	28	15,6	5	59,4	29	12,8	6
Dragasani	280	21,7	25,3	3,6	C	37,3	28	14,2	4	*42,1*	*30*	16,1	4
Apa Neagra	250	20,5	23,6	3,1	C	37,2	28	13,2	4	43,7	29	11,1	5
Tg. Jiu	210	21,3	25,0	3,7	C	38,5	28	14,6	4	61,2	11	11,1	5
Polovragi	546	19,7	23,0	3,3	C	36,0	28	13,3	3	58,4	14	*9,0*	3
Rm. Valcea	243	21,2	24,4	3,2	C	36,9	28	15,1	4;5	62,3	18	12,0	5
Voineasa	587	**17,1**	*19,6*	*2,5*	C	*34,4*	*28*	*9,3*	*5*	-	-	-	-
Parang	1585	-	-	-	-	28,0	28	4,8	5	-	-	-	-
Average Oltenia	-	21,5	24,8	3,3	-	33,5	28	10,2	-	50,9	-	13,8	-
Ob. Lotrului	1404	12,5	15,1	2,6	C	25,8	27	7,5	3	-	-	-	-

(Source: data processed from the ANM Archive)

The monthly minima of air temperature were recorded on 3, 4 and 5.VII and ranged between 9.3°C at Voineasa (5.VII) and 15.6°C at Tg. Logrești (5.VII), and their average for the entire region was 10.2°C.

The monthly maximum air temperatures were recorded mostly on 28.VII and were between 34.4°C at Voineasa (28.VII) and 40.0°C at Bechet (29.VII), and the average their temperature for the whole region was 33.5°C. ***In the warmest area of Oltenia, in the "Sahara of Oltenia" in Dăbuleni[3] was recorded 40.4°C on 28.VII.2021.***

At the soil surface, the monthly maximum temperatures were recorded on 7, 11, 12, 14, 18, 29, 30 and 31.VII and were between 42.1°C at Drăgășani on 30.VII and 62.3°C at Rm. Vâlcea on 18.VII.2021. The minimum temperatures at the soil surface were recorded, most of them, between 3 and 6.VII and were between 9.0°C at Polovragi on 3.VII and 17.6°C at Calafat on 3.VII, and their average for the whole region was 13.8°C.

In July there were ***3 heat waves*** in the intervals: ***6-9.VII (4 days)*** considered ***the second heat wave of the summer***, which was a weak wave with a maximum intensity of 35.8°C at Dr. Tr. Severin on 7.VII.2021; ***the third heat wave of summer between 11-19.VII (9 days)*** with a maximum intensity of 37.4°C in Calafat on 13 and 18.VII; and ***the fourth heat wave of summer between 25.VII-5.VIII (12 days)***, the longest and most intense heat wave of the summer of 2021. ***The peaks of the fourth heat wave*** were recorded on the data of 29.VII with 40.0°C at Calafat; 1.VIII with 41.1°C at Calafat; and on 5.VIII with 40.1°C at Bechet. ***The total duration of the heat waves in July 2021*** was 20 days.

The variation graphs of the parameters that characterize the air temperature in July 2021 have increasing trends at all three parameters (average daily minima, daily average and average daily maxima) (Fig. 2), and of these the fastest increasing was the average daily maxima (calculated for the whole region) whose growth rate was 0.1473.

[3] The meteorological station of the **C.C.D.C.P.N.** Dăbuleni research station is not part of the ANM network and has not the same type with those from the ANM network, so it cannot be taken into account for comparisons

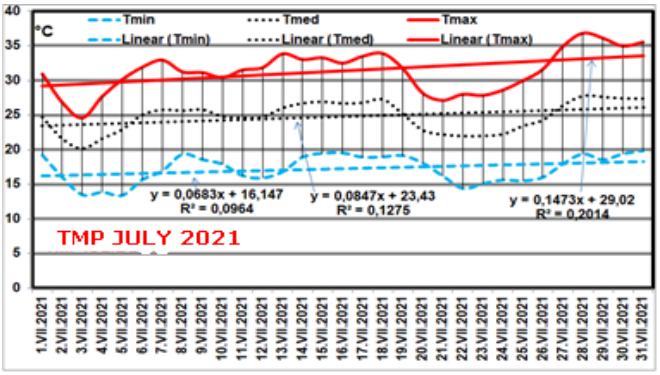

Fig. 2. *Variation of average air temperatures, daily maximums, daily averages and daily minimums calculated for the entire Oltenia region in July 2021.* (Source: data processed from the ANM Archive).

Rainfall in July

The monthly precipitation amounts were between 15.4 l/m^2 at Tg. Logrești and 60.9 l/m^2 at Voineasa, and their deviations from normal were all negative, between -73.2% at Apa Neagră and -12.3% at Caracal. According to the Hellmann Criterion, July 2021 was excessively dry (ES) in the extreme west of the region at Dr. Tr. Severin, in the centre of Oltenia at Craiova, in the south of the Oltenia Hills at Tg. Logrești and in the sub-Carpathian depressions at Apa Neagră, Polovragi and Tg. Jiu; very dry (FS) in the extreme south at Bechet, in the Olt Corridor at Rm. Vâlcea, in the Voineasa Intra-mountain Depression and in the mountain area at Parâng; dry (S) in the extreme southwest at Calafat, in the Getic Piedmont at Slatina and in the Olt Corridor at Drăgășani and slightly dry (PS) at Romanați Plain at Caracal. So the drought with different degrees of intensity covered the whole of Oltenia. The average monthly rainfall was 37.0 l/m^2, and the percentage deviation from its normal was -43.0% which shows that on average July was very dry (FS) for the entire Oltenia region. At the end of July 2021 in the cultivation of unirrigated corn, the water reserve on the soil profile 0-100 cm was located in satisfactory limits and close to optimal, in almost all regions. The soil moisture content was low, the pedological drought being moderate (ANM)

3.3. Climate characteristics of August 2021

The thermal regime of August 2021

The monthly averages of the air temperature were between 17.8°C at Voineasa and 25.5°C at Calafat, and their deviations from normal were between 1.3°C at Tg. Logrești and 3.2°C at Dr. Tr. Severin. According to the Hellmann Criterion in August 2021 the weather was warm (C) in most of Oltenia and warm (CL) on small areas at Bechet, Tg. Logrești, Voineasa and Ob. Lotrului (Table 4). *The monthly average air temperature* for the entire region was 23.3°C (1.5°C lower than in July), and its deviation from normal was 3.3°C.

According to the Hellmann Criterion, August was warm (C) on average for the whole Oltenia region. *The monthly maximum air temperatures* were mostly recorded on 1.VIII at the height of ***the fourth heat wave of summer*** and were between 33.6°C at Voineasa and 41.1°C at Calafat (both on 1.VIII). The average monthly maxima for the entire region was 37.8°C, 4.3°C higher than in July. The monthly minima of air temperature were reached on 28.VIII and were between 7.0°C at Voineasa and 14.9°C at Drăgășani, and their average for the entire region was 11.2°C, higher by 1.0°C than in July.

Table 4. *Oltenia air temperature regime, and minimum and maximum ground surface temperature values in August 2021* (Hm = station altitude, Δ = MN = deviation from the average temperature in August 2021, CH = Hellmann Criterion, NVIII = temperature averages in August calculated for the period 1901-1990 - normal; MVIII = temperature averages in August 2021)

Meteorological Station	Hm	NVIII	MVIII	Δ=M-N	CH	Tmax air		Tmin air		Tmax soil		Tmin soil	
						(°C)	Date	(°C)	Date	(°C)	Date	(°C)	Date
Dr.Tr.Severin	77	22,2	25,4	3,2	C	**39,1**	1	12,7	28	43,9	1	9,8	28
Calafat	66	22,7	25,5	**2,8**	C	41,1	1	13,3	28	45,7	1	16,7	28
Bechet	65	22,4	24,1	**1,7**	CL	**40,4**	1	11,1	28	47,6	16	15,3	28
Băilești	56	22,5	24,8	**2,3**	C	**39,2**	1	11,0	28	51,3	10	11,5	28
Caracal	112	22,4	24,9	**2,5**	C	**39,6**	1	14,4	28	*43,1*	*12*	14,8	28
Craiova	190	22,2	24,5	**2,3**	C	**38,0**	2	12,9	28	48,0	1	12,6	28
Slatina	165	22,2	24,4	**2,2**	C	**38,5**	2	11,9	28	45,7	16	12,0	28
Bâcleș	309	20,9	23,4	**2,5**	C	**37,5**	1	13,1	28	-	-	-	-
Tg. Logrești	262	20,2	21,5	*1,3*	CL	**36,7**	1	8,8	28	58,4	11	8,0	28
Drăgășani	280	21,5	24,2	**2,7**	C	**37,1**	1;2	14,9	28	53,1	16	14,9	28
Apa Neagră	250	20,1	21,5	**1,4**	CL	**37,6**	1	6,8	28	43,2	1	8,2	28
Tg. Jiu	210	20,9	23,3	**2,4**	C	**37,6**	1	10,1	28	60,2	1	7,2	28
Polovragi	546	19,4	21,9	**2,5**	C	**34,5**	1	9,2	28	57,1	1	*6,2*	*28*
Rm. Vâlcea	243	20,5	23,1	**2,6**	C	**36,3**	2	10,9	28	62,3	17	8,2	28
Voineasa	587	16,3	17,8	**1,5**	CL	*33,6*	1	*7,0*	*28*	-	-	-	-
Parâng	1585	-	-	-	-	**25,5**	9	7,2	26	-	-	-	-
Average Oltenia	-	21,1	23,3	**2,2**	C	**37,8**	-	11,2		50,7	-	11,2	-
Ob. Lotrului	1404	11,8	12,9	**1,1**	CL	27,6	*1*	3,5	28	-	-	-	-

(Source: data processed from the ANM Archive)

The maximum value of 40.4°C recorded at Bechet on 1.VIII.2021 is the third value in descending order from the whole data set for this meteorological station; 39.6°C was recorded at Caracal on 1.VIII as the fourth in descending order; and ***41.1°C was recorded at Calafat on 1.VIII as the fifth in descending order***, for this meteorological station and also ***the thermal maximum for the whole country on 2021***. In the warmest area of Oltenia, in the "Sahara of Oltenia" ***at Dăbuleni was recorded 41.2°C on the dates of 1, 2 and 5.VIII.2021***. All this shows that in August the heat intensity increased. The heat waves in August continued: ***in the interval 1-5.VIII (5 days) the fourth heat wave continued; in the interval 8-17.VIII (10 days) the fifth heat wave was registered with the maximum intensity of 39.8°C at Calafat*** on the 9.VII, and in the interval of 20-24.VIII (5 days) the 6th heat wave of the summer was registered with the maximum intensity of 35.7°C at Calafat on the 23.VII. We

note that ***in August the heat waves were present for 20 days***, the same in July. Therefore, in total during the summer of 2021 there were 50 days in which the heat waves appeared (54.3% of the summer days).

In all summer months and especially in July and August, there were many days when temperatures exceeded the heat (32.0°C) and heatwave threshold (35.0°C). ***The graphs of the parameters' variation that characterize the air temperature*** in August 2021 have decreasing trends at all three parameters (daily minimum average, daily average and daily maximum average) (Fig. 3), and of these the fastest decreasing was the average daily maximum (calculated for the whole region) whose decreasing coefficient was -0.3364. The appearance is due to the decrease of the length of the day, being known that on the 15 or 16.VII the length of the night reaches and then exceeds 10 hours and the nights cool down, and the summer heat gradually diminishes.

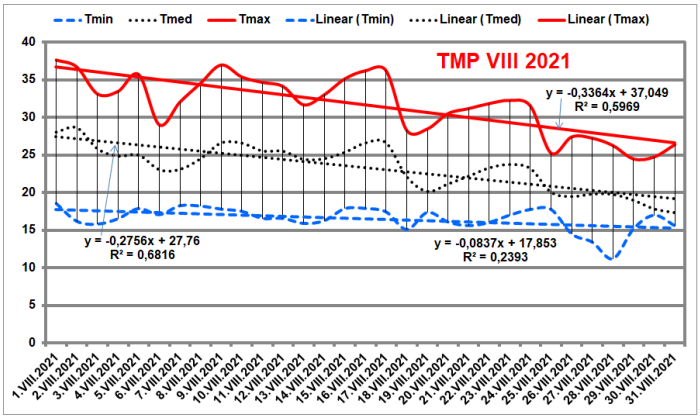

Fig. 3. *Variation of air temperature averages, daily maximums, daily averages and daily minimums calculated for the entire Oltenia region in August 2021* (Source: data processed from the ANM Archive).

In the time interval 15.VIII-8.IX, as a result of the gradual installation of the polar night that ends at the autumn equinox, ***the polar climate front*** slowly begins its migration to the south (due to the progressive cooling of the air in the area of the North Pole). Therefore, slow processes take place in the Earth's atmosphere, the air currents reorient slowly but surely to the south, so the migratory birds waiting in the south of the continent, the currents heading south to help them cross the Mediterranean Sea are sometimes confused by warm currents, which still pulses north. Many creatures are confused by the hot days and forget that autumn is soon beginning and then winter is coming. Even plants have beneficial time intervals in which they vegetate like in summer. The vineyards begin to ripen, the peppers turn red, the autumn crops ripen quickly, etc. For people, atmospheric calm and warm weather are beneficial.

At the surface of the soil the monthly maximum temperatures were reached in the range 1-17.VIII and were between 43.1°C on 12.VIII in Caracal

and 62.3°C at Rm. Vâlcea on 17.VIII.2021 (equal to that of July), and ***their average for the entire Oltenia region*** was 50.7°C, lower by 0.2°C than that of July. The monthly minimum temperatures at the surface of the soil were achieved on 28.VIII and were between 6.2°C at Polovragi and 16.7°C at Calafat.

Rainfall in August

The monthly precipitation quantities were between 2.6 l/m^2 at Calafat and 98.9 l/m^2 at Voineasa, and their percentage deviations from normal were between -92.7% at Calafat and 35.9 % la Voineasa. According to the Hellmann Criterion, August 2021 was excessively dry (ES) in most of Oltenia and dry (S) on restricted areas in the Olt Corridor at Drăgășani and Rm. Vâlcea, normal (N) at Tg. Logrești, Apa Neagră and Parâng and very rainy (FP) in the Voineasa Intra-mountain Depression, due to local conditions. The monthly average of precipitation amounts for the entire Oltenia were 32.4 l/m^2, being the lowest during this summer and during the first 8 months of 2021, and its percentage deviation was -38.1% which according to the Hellmann Criterion shows that August was very dry (FS) on average for the whole Oltenia region (Table 2).

On August 31, 2021, in the culture of non-irrigated corn, the water supply of the soil on the depth of 0-100 cm presents satisfactory values, close to optimal and optimal, isolated in eastern Oltenia. Soil moisture deficits (moderate and severe pedological drought) were recorded on large agricultural areas in Oltenia (ANM).

Seasonal climatic characteristics of summer 2021

The seasonal averages of air temperature were between 17.9°C at Voineasa and 25.1°C at Dr. Tr. Severin, and their deviations from normal were between 1.6°C in Bechet and 3,1°C at Dr. Tr. Severin (Table 5). According to the Hellmann Criterion, the summer of 2021 was as a whole warm (C) in most of Oltenia and warm (CL) on the restricted areas at Bechet, Slatina, Tg. Logrești, Voineasa and in the mountain area at Ob. Lotrului.

The seasonal average air temperature for summer 2021 calculated for the entire region was 22.9°C, and its deviation from normal was 2.2°C which confirms that summer 2021 was warm (C) on average for the whole Oltenia region.

The seasonal amounts of precipitation were between 59.0 l/m^2 at Dr. Tr. Severin and 300.1 59.0 l/m^2 at Voineasa, and their percentage deviations from normal were between -63.1% to Dr. Tr. Severin and 11.9% to Voineasa. According to the Hellmann Criterion, in the summer of 2021 it was excessively dry (ES) in Dr. Tr. Severin Calafat, Băilești and Polovragi; very dry (FS) at Slatina, Apa Neagră, Polovragi and Rm. Vâlcea; drought (S) in Craiova, Tg. Logrești and Parâng (in the mountain area); slightly dry (PS) at Bechet; normal pluviometric (N) at Caracal in Câmpia Romanațiului and slightly rainy (PP) at Voineasa.

Table 5. Overall rainfall and thermal regime of summer 2021 (Hm = station altitude, V2021 = average temperature values in summer 2021 (°C), Nv = normal seasonal temperature averages in summer (°C), Δ = V-Nv = deviations from average of normal temperatures (°C) CrH = Hellmann Criterion, S = sum of precipitation in summer 2021 (l/m^2), N = normal values of summer precipitation (l/m^2), Δ = SN = deviations from normal (l/m^2), Δ% = percentage deviations from normal).

Meteorological Station	Hm	Thermal regime (°C)				Pluviometric regime (l/m^2)				
		V2021	Nv	Δ=V-Nv	CrH	S	N	Δ=S-N	Δ%	CrH
Dr. Tr. Severin	77	*25,1*	22,0	*3,1*	C	*59,0*	160,0	-101,0	*-63,1*	ES
Calafat	66	25,0	22,3	2,7	C	68,6	146,8	-78,2	-53,3	ES
Bechet	65	23,8	22,2	*1,6*	CL	121,2	146,8	-25,6	-17,4	PS
Băileşti	56	24,3	22,1	2,2	C	74,3	150,5	-76,2	-50,6	ES
Caracal	112	24,0	22,0	2,0	C	171,8	167,4	4,4	2,6	N
Craiova	190	23,8	21,7	2,1	C	115,5	164,7	-49,2	-29,9	S
Slatina	165	23,5	21,6	1,9	CL	94,2	184,9	-90,7	-49,1	FS
Bâcleş	309	23,0	20,4	2,6	C	135,6	152,5	-16,9	-11,1	PS
Tg. Logreşti	262	21,6	19,9	1,7	CL	135,2	165,4	-30,2	-18,3	PS
Drăgăşani	280	23,4	20,9	2,5	C	130,0	185,6	-55,6	-30,0	S
Apa Neagră	250	21,6	19,1	2,5	C	131,1	232,0	-100,9	-43,5	FS
Tg. Jiu	210	23,0	20,5	2,5	C	122,3	219,2	-96,9	-44,2	FS
Polovragi	546	21,3	18,9	2,4	C	136,6	277,7	-141,1	-50,8	ES
Rm. Vâlcea	243	22,6	20,2	2,4	C	151,6	254,3	-102,7	-40,4	FS
Voineasa	573	*17,9*	16,2	1,7	CL	300,1	268,1	32,0	11,9	PP
Parâng	1585	-	-	-	-	275,4	346,8	-71,4	-20,6	S
Average Oltenia	-	22,9	20,7	2,2	C	138,9	201,4	-62,5	-31,0	FS
Ob. Lotrului	1348	13,3	11,7	*1,6*	CL	218,3	-	-	-	-

(Source: data processed from the ANM Archive)

3.5. Heat wave in the period 25.VII-5.VIII

In July and August the air temperature remained high throughout the country and over much of Europe, the increase in heat intensity was like a continuous heat wave. The delimitations of the 6 heat waves were made due to short time intervals in which the air temperature decreased by 3 ... 4°C. The heat wave between 25.VII-5.VIII was the most intense in the last 4 years and holds the climate record of ***the longest intense heat wave in the history of meteorological observations***. The continuous persistence of particularly hot and dry air has affected all agricultural crops and has greatly aggravated the situation in the area of "Sahara Oltenia" which covers 6.0% of the area of Doll County (at least 100,000 ha), and during heat waves expand almost doubling. The wave reached the maximum intensity of 41.1°C at Calafat on 1.VIII, and at Dăbuleni in the central area of the vast area where the aridization phenomena are intensely manifested, the maximum intensity was 41.2°C on 1, 2 and 5.VIII. We will analyse the synoptic causes of this heat wave.

On 1.VIII.2021, at 18 UTC, at the level of the land surface, the distribution of the main baric centres was as follows: on the Atlantic Ocean was present the Azores Anticyclone with atmospheric pressure values in the central

part ≥1030 hPa (Fig. 4); on the Great Russian Plain was present the Eastern European Anticyclone, poorly developed with centre values slightly higher than 1015 hPa. Most of Europe was dominated by a vast field of the basin of a former Icelandic atmospheric depression originally positioned, now above the Scandinavian Peninsula with values of atmospheric pressure at the centre < 1000 hPa. Above Romania, the atmospheric pressure values were between 1005 hPa in the west of the country and a little over 1010 hPa in the east. In western Romania there was a weak cyclonic zone, of thermal nature with centre values slightly lower than 1005 hPa, formed in the Icelandic Cyclone basin. This small cyclonic formation had an important role in amplifying the hot air advection, over Romania on this date.

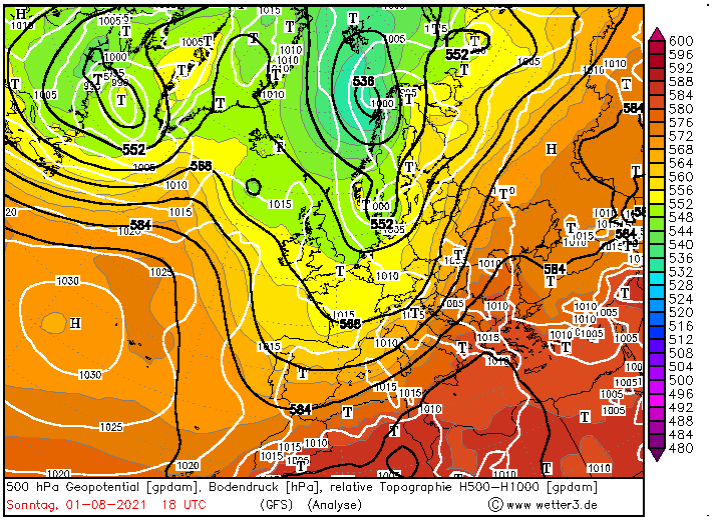

Fig. 4. *Geopotential field at the level of 500 hPa and relative topography TR500 / 1000 superimposed with the field of atmospheric pressure at the level of the earth's surface on 1.VIII.2021 at 18 UTC* (at the moment of reaching the peak of the heat wave). (after www.wetter3.de)

In altitude at the level of 500 hPa (about 5000 m altitude) the distribution of the geopotential field, presented a vast area of high geopotential in the south of the continent with values over 592 hPa. For Romania, the air circulation at this level was Tropical Continental (cT), advecting particularly hot air from North Africa. ***At the level of 850 hPa*** (about 1500 m altitude), above the Oltenia was positioned the isotherm of 25.0°C, and the isotherm of 20.0°C was positioned north of Romania, encompassing the whole country in the area of particularly hot air.

The isotherm of 26.0°C was positioned tangent along the Danube, above western Bulgaria and western Greece. All this explains the high intensity of the advection of particularly hot air from North Africa, over the Balkan Peninsula and Romania since 1.VIII. The warm air stagnated and continued to heat during the long summer days lasting over 14 hours and 30 minutes, which

caused ***secondary peaks of the heat wave from*** the data of 2.VIII (39.7°C at Bechet), 5.VIII (40.1°C at Bechet), 9.VIII (39.8°C at Calafat) and 16.VIII (39.1°C at Calafat).

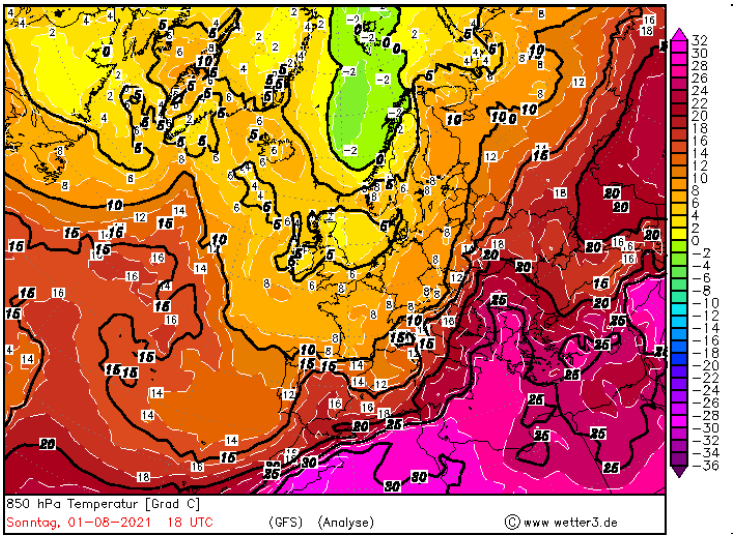

Fig. 5. *Temperature field at the level of 850 hPa on 1.VIII.2020 at 18 UTC* (at the moment of reaching the peak of the heat wave). (after www.wetter3.de)

The value of the thermal comfort index (ITU) reached 83.8 units in Calafat and 83.7 in Dr. Tr. Severin and Băilești (1.VIII), which actually shows the intensity of the thermal discomfort caused by the heat wave. Figure 5 shows that Romania was on the edge of the "heat dome".

The particularly hot air extended in the west of the country to the north of Oradea and in the east, in Moldova, to Vaslui, and to Dobrogea to Adamclisi, Medgidia Corugea and Tulcea.

4. CONCLUSIONS

The summer of 2021 was as a whole very warm, marked by July and August with intense heat waves. The heat waves started early, so the first heat wave occurred in the interval ***22.VI-1.VII (10 days)***, the second in the interval ***6-9.VII (4 days)***, the third in the interval ***11-19.VII (9 days)***, the fourth in the interval ***(25.VII-5.VIII) (12 days)***, the fifth in the interval ***8-17.VIII (10 days)*** and the sixth in the interval ***20-24.VIII (5 days)***. The total duration of the heat waves was 50 days, which means 54.3% of the summer days. The most intense heat wave was registered between 25.VII-5.VIII and lasted 12 days. Several peaks of heat waves were recorded on 25.VI with an intensity of 39.3°C in Calafat, 30.VI with an intensity of 38.3°C in Calafat, 7.VII with an intensity of 35, 8°C at Dr. Tr. Severin, 13.VII with an intensity of 37.4°C at Calafat, 14.VII

with an intensity of 37.3°C at Calafat, 18.VII with an intensity of 37.4°C at Calafat, 28.VII with an intensity of 39.4°C at Dr. Tr. Severin, 29.VII with an intensity of 40.0°C in Calafat, 30.VII with an intensity of 39.7°C in Calafat, 31.VII with the intensity of 39.0°C at Calafat, 1.VIII with the intensity of 41.1°C at Calafat, 2.VIII with the intensity of 39.7°C at Calafat, 5.VIII with the intensity of 40.1°C at Bechet, 9.VIII with an intensity of 39.8°C at Calafat, 10.VIII with an intensity of 38.4°C at Calafat, 15.VIII with an intensity of 38.9°C at Calafat, 16.VIII with intensity of 39.1°C at Calafat, 17.VIII with intensity of 38.7°C at Calafat, and 23.VIII with intensity of 35.7°C at Calafat.

The atmospheric drought started on the 1st of VI, after which there was no more rain with significant amounts of precipitation for agriculture in the plain area and only a few isolated ones in the hill and mountain area. The driest month was August, with a monthly rainfall of 32.4 l/m^2. All spring crops were severely affected, with production in some areas being about 10% of normal, especially for late crops (in May or even the second half of May). As a result, it is necessary to establish spring crops as early as possible in order to benefit from the spring rains, but in April 2021 the weather was cold, especially in the first 15 days, and the minimum temperature at the soil surface reached 9-10°C. in the morning of 30.IV. We notice the climatic record of ***the longest intense heat wave in the history of meteorological observations, in the interval (25.VII-5.VIII) (12 days).***

The climatic variability of summer 2021 was particularly high. The frequency of particularly hot and dry summers increased especially after 2015. At the European level, the summer of 2021 was ***the warmest summer recorded so far, surpassing by 0.1 ° C the summer of 2020*** (U. E. Copernicus service according to D.P.A.)

The hot summer with intense and long waves of heat and drought 2021 was recorded in atypical conditions. Thus, in August 2021, NINO.3 SST was almost normal, with a deviation of -0.3°C. SSTs in the equatorial Pacific were above normal in the west and below normal in the central and eastern parts. Surface temperatures were above normal in the western parts and below normal in the central and eastern parts. While atmospheric convective activity near the international date line over the Equatorial Pacific was below normal, easterly winds in the lower troposphere (ie trade winds) in the Central Equatorial Pacific were almost normal. These oceanic and atmospheric conditions indicate that ENSO neutral conditions persisted in August. Deep cold waters, seen in the eastern Equatorial Pacific in August, are expected to remain in the fall and temporarily reduce SSTs in the eastern parts. In conclusion, ENSO neutral conditions will continue (70%) until the northern winter" (https://ds.data.jma.go.jp/tcc/tcc/products/elnino/outlook.html)

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