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ANALYSIS OF DAILY MAXIMUM TEMPERATURES IN OLTENIA: THE SUMMER OF 2024 AS A CASE STUDY

ANALIZA TEMPERATURILOR MAXIME ZILNICE ÎN OLTENIA: STUDIU DE CAZ, VARA ANULUI 2024

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Abstract: According to Copernicus climate change service (C3S), the summer of 2024 was the warmest on record for our continent, the average surface air temperature over the European land reaching +1.54°C above the 1991-2020 average. In Romania, extremely high temperatures were recorded in July and August, heatwaves affecting particularly the southern part of the country. However, at their peak, western and eastern extra-Carpathian regions also registered extremely high temperatures. In Oltenia, there were recorded 24 daily maximum temperatures ≥40°C (20 in July and 4 in August), the area located in the proximity of the Danube being the most exposed (15 values above 40°C). In July, in four county municipalities (Drobeta-Turnu Severin, Craiova, Târgu Jiu, and Râmnicu Vâlcea), there were recorded 13 consecutive days with maximum temperatures above 35°C, while at Slatina there were 14 days (July 7/8 - July 20). In August, the interval was shorter, between 7 days at Craiova and 10 days at Drobeta-Turnu Severin (August 10/11 - August 17/18). The persistence of high atmospheric pressure formations intensified local insolation processes, which, together with tropical air advections, contributed to the increase of heating. Even if the previous thermal records (registered on July 24, 2007) were not exceeded, in terms of average temperature, the summer of 2024 was hotter than the summers of 2007 and 2012 (values above 27°C were registered at six meterological stations in July and at five in August), which triggered numerous problems in the region – agricultural losses, wildfires, power shortages, health issues.

Key-words: *daily maximum temperatures, heatwaves, 2024 summer, Oltenia*
Cuvinte cheie: *temperaturi maxime zilnice, valuri de căldură, vara 2024, Oltenia*

1. INTRODUCTION

Summer heatwaves are a serious threat to environment, economy, and public health. Extreme heat events like the ones registered in the summer of 2024 are no longer rare occurrences. According to IPCC AR6 report (IPCC, 2021), heatwaves

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increased in intensity, number, and duration at the global scale and further increase is expected in the future. The same report also indicates not only greater heatwaves durations but also higher maximum temperatures compared to the ones registered so far. At continental level, the most exposed region to extreme temperature and heatwaves is Southern Europe, particularly the Mediterranean area (Tejedor et al., 2024). According to Copernicus Climate Change Service (C3S), the summer of 2024 was the warmest on record, the average surface air temperature over the land reaching +1.54°C above the 1991-2020 average and +0.2°C above the previous warmest summer (2022). June 2024 is indicated as the second warmest on record for Europe, but the warmest for Southeastern Europe and Turkey (C4S, 2024a). July also registered high temperatures (the second warmest month at European level after July 2010), namely 1.49°C above the 1991-2020 average, Southern and Eastern Europe being indicated as regions with temperatures above the average (C4S, 2024b). Heatwaves affected the Mediterranean region, the Balkan Peninsula, but also Romania. The same pattern was registered in August, when the mean temperature was 1.57°C above the 1991-2020 average (C4S, 2024c), the month being considered the second-warmest on record for Europe after August 2022; besides Italy, Portugal, Spain, heatwaves were registered in Romania, Serbia, and Bosnia.

Under these circumstances, Romania, especially the southern part, is particularly prone to high temperatures and heatwaves. Consequently, heatwaves preoccupied the Romanian researchers in the last 20 years. Croitoru & Piticar (2013) indicate an increasing trend in the frequency of heatwaves over the extra-Carpathian regions of Romania and in the daily maximum temperature compared to the daily minimum temperature. Barbu et al. (2014) analysed heatwaves between 1983 and 2012 based on the maximum daily temperature greater than the 90th percentile for at least three days (1961–1990 reference period), identifying 2144 events at 105 stations. According to Bojariu et al. (2015), the meteorological stations located along the Danube register a statistically significant upward trend with regard to the number of days included in heatwaves. Upward trends of the indices characterizing heatwaves were identified by Croitoru et al. (2016) for the period 1961-2015. The trend defined on the basis of maximum temperature was stronger than the one defined on the basis of minimum temperature, the most exposed regions of the country being the western and central ones. Bades on daily maximum temperatures, Sfîcă et al. (2017) also indicated a significant upward trend of the number of days included in heatwaves for the same period and an increase in the number of heatwave days during the last 15 years of the study period. Piticar et al. (2018) used the excess heat factor to analyse heatwaves in Romania and emphasize that they became more frequent, longer, and more intense. 97% of the analysed data sets were statistically significant in terms of upward trends for heatwave number and frequency.

Nagavciuc et al. (2022) studied the hot and dry summers in Romania between 1950 and 2020. They used the 90th percentile of the daily maximum temperature based on a 15 days window centered on each calendar day and a duration of 5 consecutive days. Their analysis revealed the increase in length,

spatial extent, and frequency of heatwaves for all summer months. Antonescu et al. (2023) analysed heatwaves based on the excess heat factor (EHF) highliting a longer annual duration of heatwaves particularly in southern and southeastern Romania, a statistically significant increasing trend in the number of days with positive EHF for most of the country, but not significant in terms of the number of heatwaves in southern Romania. Ionita et al. (2024) identified statistically significant upward trends in the summer days (T_X>30°C) across Romania over the past 140 years and the strongest heatwaves detected according to the threshold-based method are those registered in August 1946, August 1952, July 2012, June 2019, and August 2023.

The main aims of this research are: (i) to analyse the daily maximum temperatures in Oltenia Region in the three summer months of 2024; (ii) to asses the synoptic situation that triggered these extreme heat events; (iii) to compare the situation registered in 2024 to the previous two hot summers – 2007 and 2012.

2. DATA AND METHODS

2.1 Study area

Oltenia region, located in the southwestern part of Romania, is characterized by a great altitudinal range, from about 30 m to 2519 m (Badea et al. 1983) as it includes a variety of landforms, starting from the Danube Floodplain in the south to the Carpathian Mountains – Parâng and Retezat Godeanu in the north (Fig. 1).

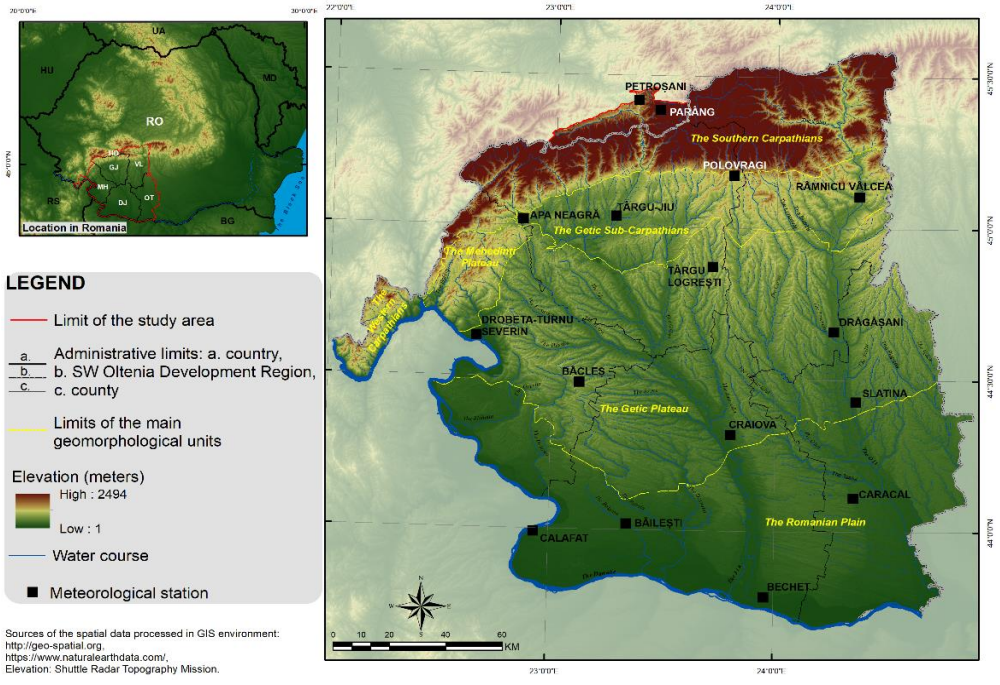


Fig. 1 Location of Oltenia Region within Romania and position of the considered meteorological stations

2.2 Data

There were used the following data for the summer of 2024: mean monthly temperatures and daily maximum temperatures from 16 meteorological stations located in Oltenia. The synoptic situations registered on July 16 and August 13, 2024 were also analysed. For comparison, there were used temperature data (mean monthly and daily maximum values) registered in the summer of 2007 and 2012, two of the hottest summers on record. Data were provided by the National Meteorological Administration (NMA) and retrieved from the European Climate Assessment & Dataset (ECA&D).

2.3 Methods

For the present study, there were analyzed the synoptic maps from the international weather forecasting centers for the 2024 summer months. Temperature data (mean monthly values and daily maximum values) from the 16 meteorological stations located in Oltenia Region were processed and compared to the values registered in 2007 and 2012.

The need for a continuous, spatially-distributed image of climate variables as a prerequisite for the development of stochastic models integrated in refined assessments of climate impact, alongside with the uneven distribution of stations that register climatological variables and with the diversity of further control factors has led to a rich literature tackling the techniques used to interpolate localized climatological recordings (Jarvis & Stuart, 2001; DeGaetano & Belcher, 2007; Hofstra et al., 2008, Sluiter, 2009; Feng et al., 2024).

In order to estimate the daily maximum temperatures within the areas lacking monitoring infrastructure, the present study used the available data for 16 meteorological stations located in Oltenia, as well as data from 12 support stations placed in the nearest Romanian, Serbian, and Bulgarian areas, all information being processed and represented in GIS environment.

After comparing four versions of interpolation methods in the particular context of Oltenia, with a rather homogenously distributed meteorological network, compounded by topographic complexity, we selected the Spline tension method, integrated in the ArcGIS Spatial analyst tools, as the most appropriate for the estimation of the daily maximum temperatures for the entire area under study. The data thus generated and analyzed are included in the present study.

3. RESULTS AND DISCUSSIONS

3.1 Overview of the summer 2024 temperature

In Romania, extremely high temperatures were recorded in July and August, but June also marked different temperature-related records, heatwaves affecting particularly the southern part of the country. However, at their peak, western and eastern extra-Carpathian regions also registered extremely high temperatures.

June: According to NMA (2024a), in Oltenia – the plain area and the Jiu and the Olt valleys up to the Subcarpathians, there were between 21 and 25 tropical days (daily maximum temperatures >30°C), while in the Getic Piedmont and in the southern part of the Subcarpathians, between 16 and 20 such days. The north-

eastern part of the region was particularly affected, as there was registered a deviation of +18 tropical days compared to the mean of the standard reference interval (1991-2020). The southern half of Oltenia recorded between 6 and 10 days with daily maximum temperatures >35°C (canicular days), among the highest in the country, especially during the June 19 - June 23 interval. Most of these values were between 36 and 37°C, the highest one at Rm. Vâlcea, i.e. 37.2°C on June 20. Two heatwaves were identified, the first of which occurred in the first part of the month and the second one started on June 17 and lasted for 13 consecutive days.

July: July 2024 was the second hottest in Romania (mean monthly temperature) after July 2012. Even if there were not established new thermal records in Oltenia, there were registered 20 values above 40°C, the area located near the Danube being the most exposed (15 values above 40°C). The hottest day was July 16, when 7 stations registered temperatures >40°C. There were between 14 and 16 days with daily maximum temperatures >35°C (13-14 consecutive days, July 7/8 – July 20). There was also registered a high number of tropical nights (daily minimum temperatures ≥ 20°C), between 16 and 20, in the south-western part of the region, the central-eastern sector of the Oltenia Plain, and in Drăgășani area in the Getic Piedmont. The lowest number of tropical nights was in the central and western part of the Subcarpathians, 1 to 5, while in the eastern part, there were between 6 and 10 tropical nights and even 11 to 15 along the Olt valley (NMA, 2024b).

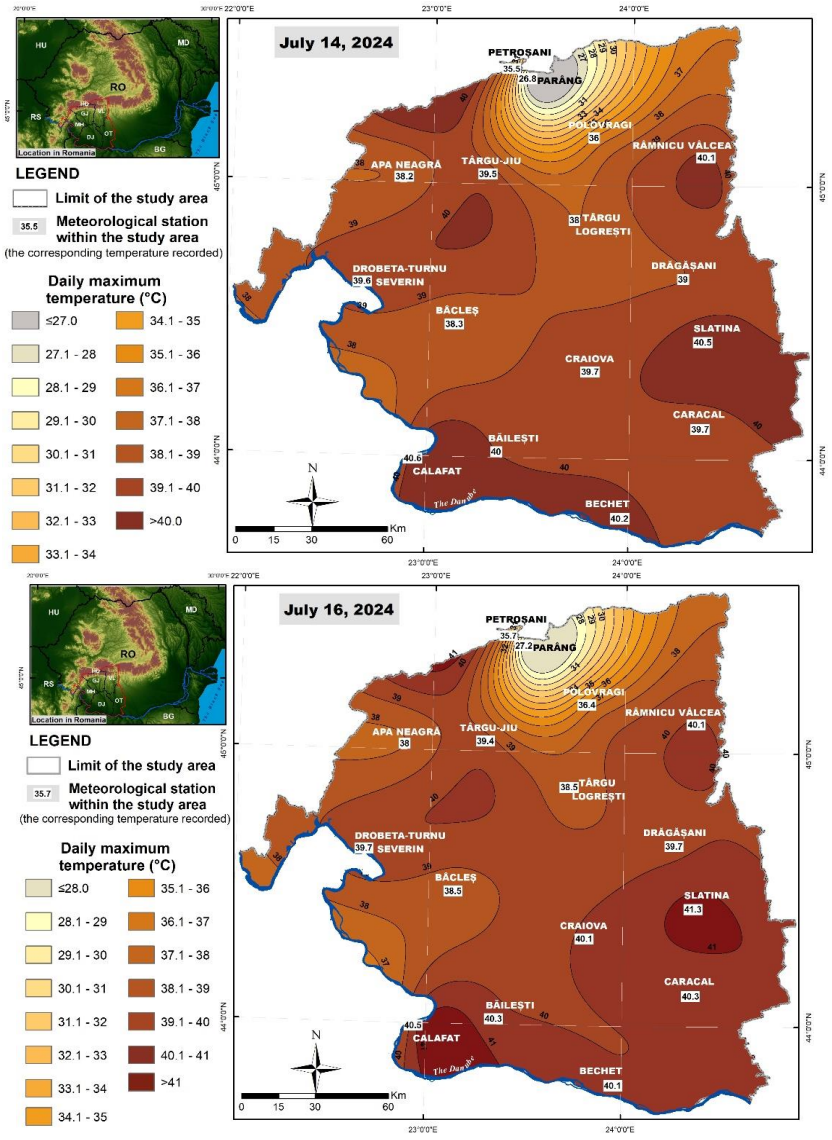
August: The average monthly air temperature at the country level reached 24.5°C (+2.9°C above the median of the standard reference interval 1991-2020), August 2024 being considered the warmest month of August recorded in Romania since 1901. In Oltenia, mean monthly temperatures varied between 25.9°C at Târgu Jiu and 27.6°C at D.T. Severin. The hottest day was August 13, when 4 stations registered temperatures ≥40°C. A new thermal record was also established at Târgu Jiu, i.e. 39.9°C, which is the highest temperature ever registered in the area. There were between 12 (Craiova) and 17 (D.T. Severin) canicular days, 7-10 of which consecutive days (August 10 – August 19). The number of tropical nights was between 16 and 20, in the south-western part of the Oltenia Plain, within Craiova and Drăgăsani areas. One to five tropical nights were also recored in the southern part of the Getic Piedmont, while in the Subcarpathins, such values were characteristic to the two important valleys from Oltenia – the Jiu and the Olt (NMA, 2024c).

3.2 July 2024 heatwave

In the second decade of July, Romania was affected by a very intense and persistent heatwave. It reached the highest intensity between July 16 and 18, when maximum temperatures of 38...41°C were recorded in all extra-Carpathian areas of the country. Throughout Oltenia, the were recorded values of 37-41°C for 3 consecutive days, with the highest values at Calafat and Slatina (Fig. 2). Temperatures during the nights remained high, so the minimum values did not drop below 21-22°C in most of the region, accentuating the thermal discomfort. Starting with July 13, a large part of the country has been under a Red Code warning, issued

for heatwave and particularly accentuated thermal discomfort, this being one of the longest periods under a Red Code.

On July 16, the first day with the extremely high temperatures, at 12 UTC, in the middle troposphere, at the level of 500 hPa, the ridge profile influencing the southeastern half of the continent can be observed, the isohypse of 588 gpdam reaching the northern part of Romania (Fig. 3).



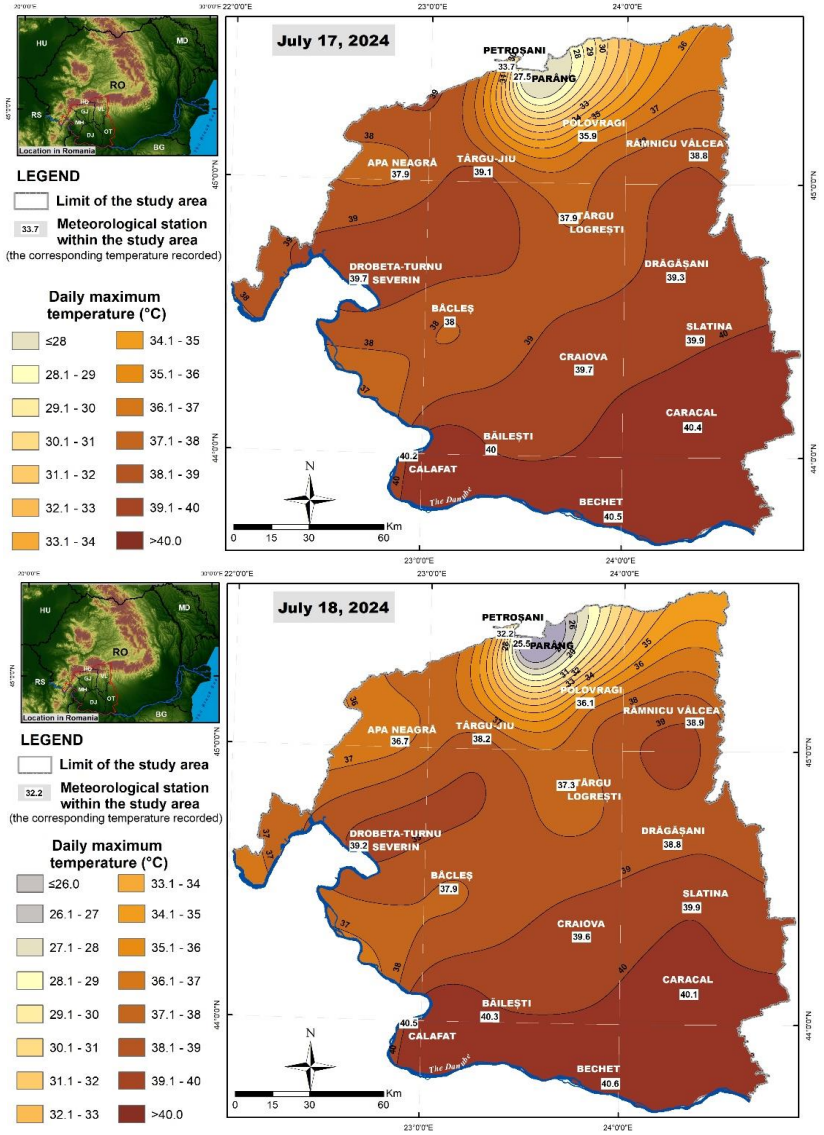


Fig. 2 Daily maximum temperatures registered on July 14, July 16-July 18

At ground level, our country was in a low-pressure field, with values below 1010 hPa. The central part of the continent was influenced by the frontal systems related to a cyclone of North Atlantic origin, the periphery of the cold front reaching the Alps. In Romania, not very well-organized convective systems developed only in the mountainous area and in the southeast of the country, favoured by the topography and the supply of moisture from the Black Sea (Fig. 4). At 850 hPa, temperature field emphasizes how the warm air mass of North African origin influences the southeastern part of the continent. The 24°C isotherm reached the south-western and the central parts of Romania. The influence of the Black Sea

is also noticeable in the southeast, temperature being slightly lower than within the rest of the territory (about 20°C) (Fig. 5).

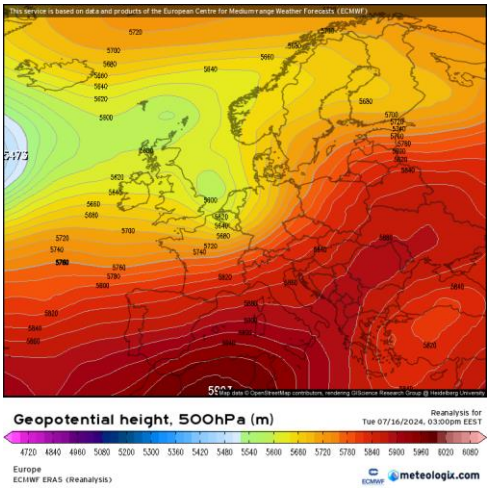


Fig. 3 The 500 hPa Geopotential height (reanalysis data ECMWF ERA5)

(Source: https://meteologix.com)

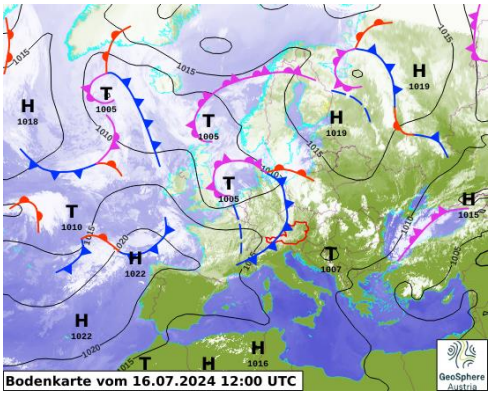


Fig. 4 Pressure and atmospheric fronts at ground level on July 16, 2024, 12 UTC

(Source: https://www.zamg.ac.at)

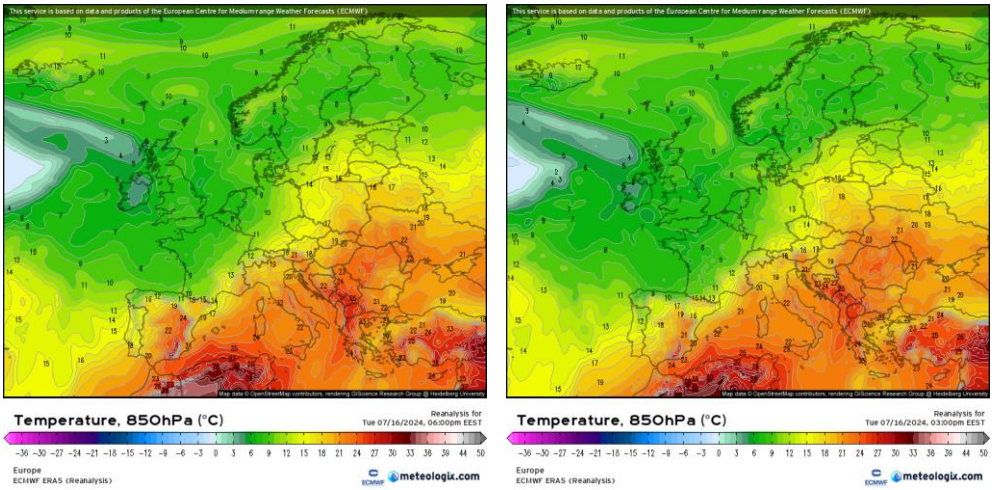


Fig. 5 Temperature at 850 hPa level (reanalysis data ECMWF ERA5), July 16: 12 UTC (left) and 15 UTC (right)

(Source: https://meteologix.com)

3.3 August 2024 heatwave

In the second case, the heatwave began to intensify on August 13, 2024 (the hottest day in Oltenia). In this case, the most affected regions were those in the western and southern part of the country (Fig. 6), where an Orange Code warning of particularly high temperatures and accentuated thermal discomfort was in force.

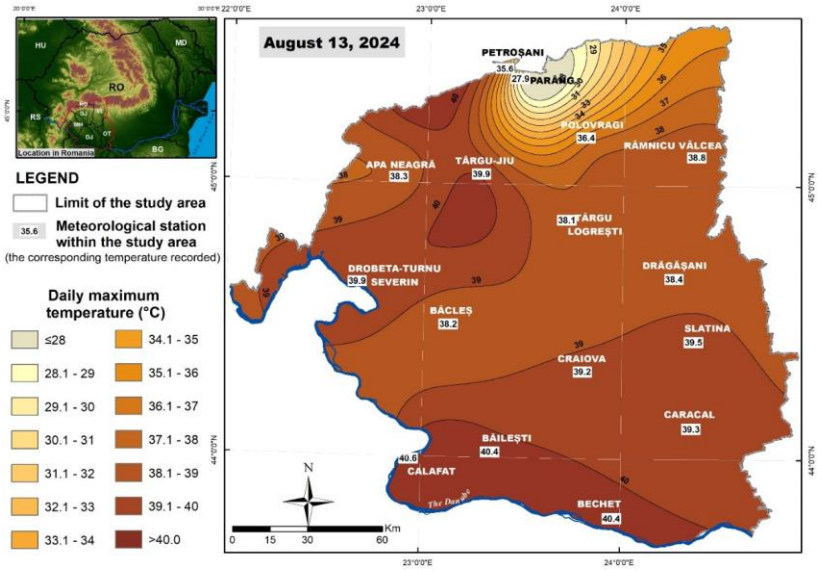


Fig. 6 Daily maximum temperatures registered on August 13

Analyzing the structure in the middle troposphere, it can be noticed that a ridge extended from Asia Minor and the Middle East to the north of the continent. On August 13, at 12 UTC, the 588 gpdam isohypse was located in the southwest of Romania (Fig. 7). At the ground level, this ridge was associated with a low-pressure field, the Arabian Depression, which extended over the Balkan Peninsula. The very dry tropical air inhibited convection and there were not convective cloud systems over the Balkan Peninsula. In Romania, the southeast circulation determined the penetration of tropical air, especially in the south and west, the northeast of the country being influenced by a colder air mass, penetrating from the north of the continent (Fig. 8).

At 850 hPa temperature field, it can be observed the advancement of the tropical air originating over the Arabian Peninsula up to the center of the continent, but also the forward motion of the tropical air originating over North Africa, which extended towards the southern part of the continent. In southwestern Romania, the air temperature was >20°C, while in the southwest of Oltenia values reached 24°C at 15 UTC. Consequently, on August 13, in Oltenia, there were registered the highest temperatures in the country (Fig. 9).

3.4 July 2024 heatwave compared to July 2007 and July 2012 heatwaves

In Oltenia, heatwaves are determined by the penetration of tropical continental airmasses originating mostly in Northern Africa and less in Asia Minor Peninsula. The summers of 2007 and 2012 were particularly hot, heatwaves characterizing all the three months as it was the case in 2024.

In ***July 2007***, the ridge of the North African Anticyclone dominated the south and southeast of Europe for days, which enabled the hot tropical continental air to easily cross the Mediterranean Sea and directly affect Italy and the entire

Balkan Peninsula and the neighboring territories, for more than 10 consecutive days (Dima et al., 2016).

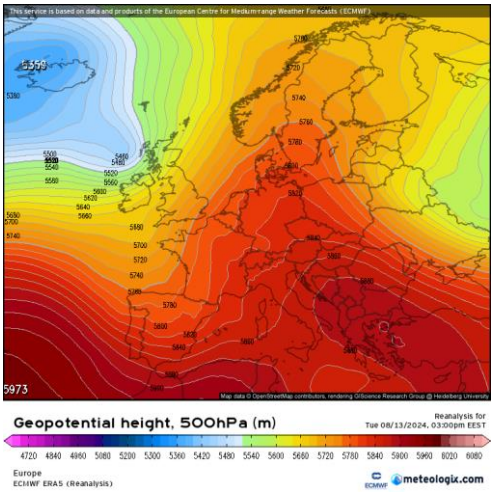


Fig. 7 The 500 hPa Geopotential height (reanalysis data ECMWF ERA5)
(Source: https://meteologix.com)

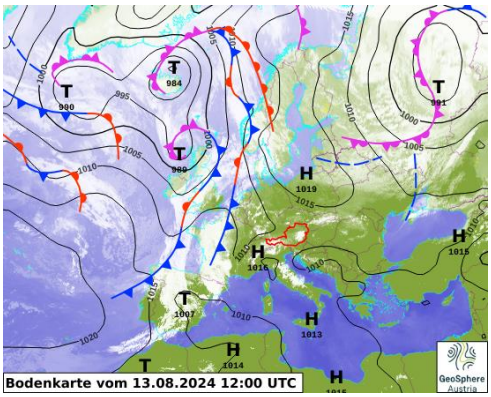


Fig. 8 Pressure and atmospheric fronts at ground level on July 16, 2024, 12 UTC
(Source: https://www.zamg.ac.at)

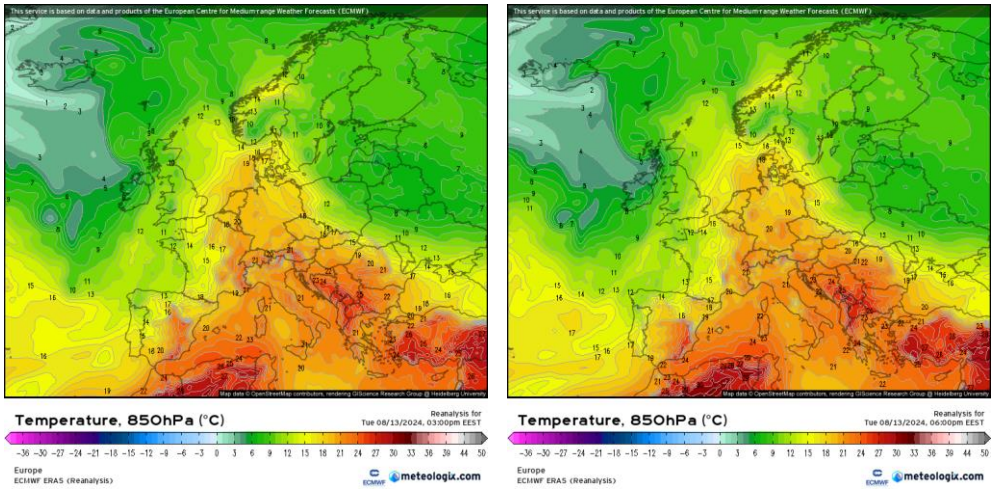


Fig. 9 Temperature at 850 hPa level (reanalysis data ECMWF ERA5), August 12: 12 UTC left and 15 UTC right
(Source: https://meteologix.com)

In Romania, the heatwave emerged on July 15, 2007 and lasted until July 25, 2007, the atmospheric pressure at ground level and at altitude during this interval confirming the permanent presence of the African ridge over the country (Figs. 10, 11) (Busuioc et al., 2007; Marinică, 2009). According to Barbu et al. (2014), who analysed the types of circulation that enabled the occurrence of heatwaves between

1983 and 2012, these are mainly associated with high pressure systems (over 70% of cases). On July 24, at 18 UTC, in southwestern Romania, temperature at 850 hPa level registered an unprecedented value – 28°C, 4°C above the maximum values from 2024 (Fig. 12). Consequently, at the ground level, maximum temperatures exceeded 44°C (Table 1), at three meteorological stations – Calafat, Bechet, and Băilești, the value registered at Calafat (44.3°C) representing the new thermal record for July in Romania (Burada & Sandu, 2009). Values ≥40°C are mentioned in the entire region except for the mountains, higher Subcarpathian area and Târgu Logrești. Thus, in terms of maximum temperatures, the July 2007 heatwave is the most intense.

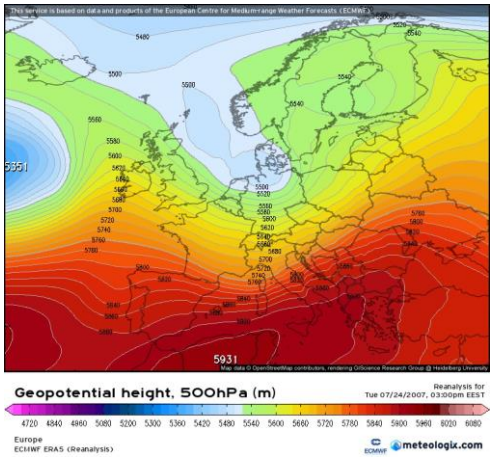


Fig. 10 The 500 hPa Geopotential height (reanalysis data ECMWF ERA5)
(Source: https://meteologix.com)

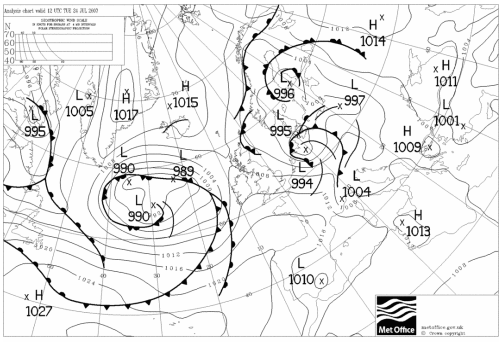


Fig. 11 Pressure and atmospheric fronts at ground level on July 24, 2007, 12 UTC
(Source: www.wetter3.de)

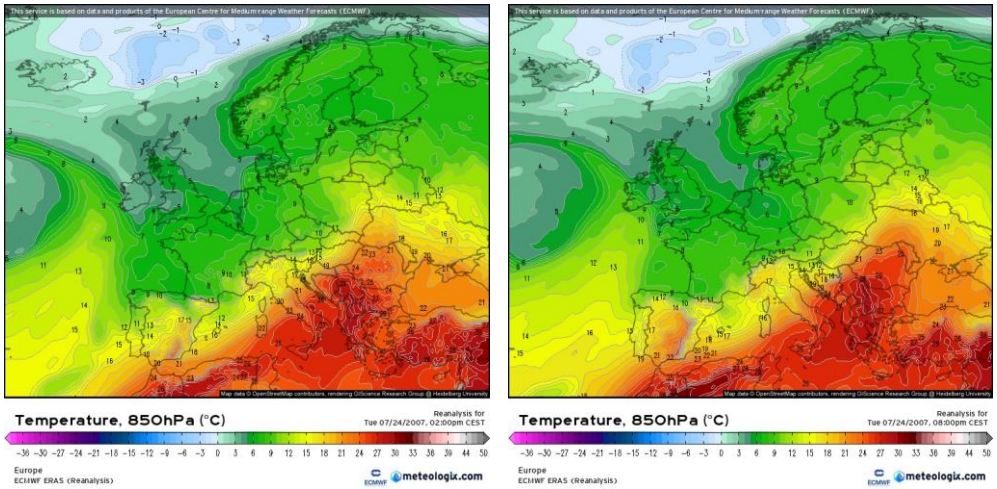


Fig. 12 Temperature at 850 hPa level (reanalysis data ECMWF ERA5), July 24: 12 UTC left and 18 UTC right
(Source: https://meteologix.com)

In ***July 2012***, in the first part of the month (July 1-16), the air circulation in the middle troposphere was from southwest, which determined the advection of a tropical air mass originating from North Africa (Figs. 13-15). Both the lower and middle troposphere were under the influence of the North African ridge. In Romania, this circulation triggered the increase in the frequency of hot days, especially in the southern and southwestern regions – the Danube Floodplain (Dima et al., 2016), where temperature exceeded 40°C at Calafat (41.6°C), Caracal and Bechet (40.7°C), and Băilești (40.5°C) (Table 1). There are mentioned 12 such values along the Danube Floodplain on July 15.

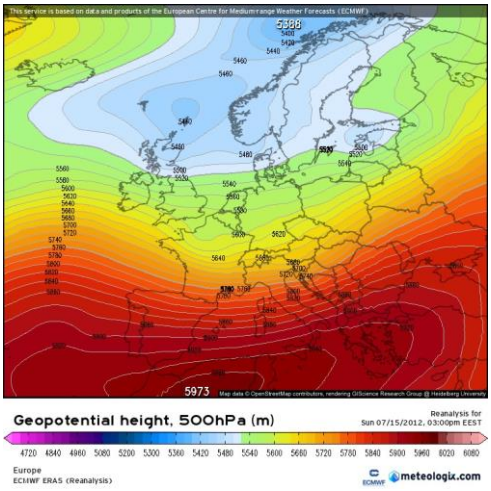


Fig. 13 The 500 hPa Geopotential height (reanalysis data ECMWF ERA5)
(Source: https://meteologix.com)

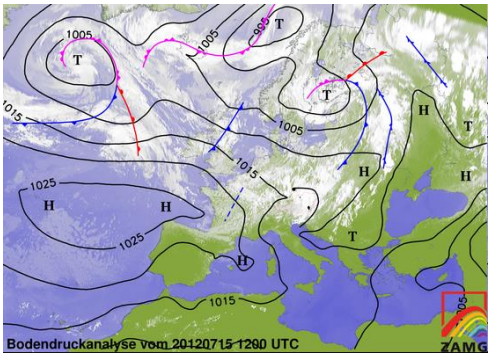


Fig. 14 Pressure and atmospheric fronts at ground level on July 15, 2012, 12 UTC
(Source: https://www.zamg.ac.at)

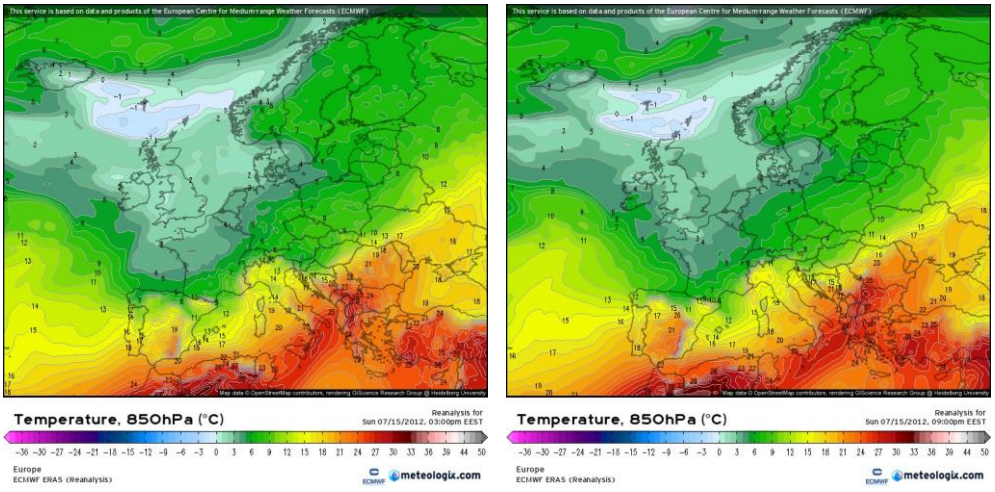


Fig. 15 Temperature at 850 hPa level (reanalysis data ECMWF ERA5), July 15: 13 UTC left and 19 UTC right
(Source: https://meteologix.com)

In the second part of the month, there is mentioned an eastern atmospheric circulation, which triggered the advection of a tropical air mass originating over the Arabian Peninsula. Consequently, 7 values ≥40°C were registered on July 21, the highest three corresponding to meteoeological stations within Oltenia: 41.3°C at Calafat, respectively 40.6°C at Băilești and Bechet.

Table 1 Daily maximum temperatures registered in Oltenia in July 2007, July 2012, July 2024

Station/Date	July 24, 2007	July 15, 2012	July 16, 2024
D.T. Severin	42.2	39.3	39.7
Calafat	44.3	41.6	40.5
Bechet	44.2	40.7	40.1
Băilești	44.0	40.5	40.3
Caracal	41.9	40.7	40.3
Craiova	42.6	39.1	40.1
Slatina	41.4	No value	41.3
Bâcleș	43.2	37.4	38.5
Tg Logrești	39.4	38.3	38.5
Drăgășani	40.6	39.0	39.7
Apa Neagră	40.6	37.8	38.0
Tg Jiu	40.7	37.5	39.4
Polovragi	36.5	35.6	36.4
Rm Vâlcea	39.8	37.8	40.1
Petroșani	36.4	34.4	35.7
Parâng	28.4	No value	27.2

Thus, the highest daily maximum temperatures correspond to July 2007, while the most numerous values above 40°C to July 2024 (20 values).

Even if the previous thermal records (registered on July 24, 2007) were not exceeded, in terms of average temperature, the summer of 2024 was hotter than the summers of 2007 and 2012 (Fig. 16).

According to NMA (2024a), ***June 2024*** has been the warmest recorded in Romania since 1901, with a positive deviation of 3.0°C compared to the median of the standard reference interval (1991-2020) at the level of the entire country. In Oltenia, positive deviations ranged between 4.6°C at Drăgășani and 2.4°C at Apa Neagră. Thus, mean monthly values were above 24°C in the plain, most of the piedmont area, and the Jiu and the Olt Valleys in the Subcarpathians. There were more than 26°C at Caracal and more than 25°C at Calafat, Băilești, Craiova, Slatina, and Drăgășani. As compared to July 2007 and July 2012, the difference is

less than 1°C at D.T. Severin, while in case of the other stations it reaches about 2°C and even more.

July 2024 with a mean temperature of 25.1°C and a positive deviation of 3.2°C was the second warmest month on record (1901-2024) after July 2012 (NMA, 2024b). In Oltenia, mean monthly temperatures exceeded 27°C at D.T. Severin, Calafat, Băilești, Caracal, Craiova, Drăgășani and 26°C at Bechet, Slatina, Bâcleș, Târgu Jiu, Râmnicu Vâlcea. Compared to the previous years, temperature was higher than the value registered in 2012 at six meteorological stations (D.T. Severin, Calafat, Băilești, Craiova, Drăgășani and Rm. Vâlcea), the highest mean temperatures being registered at Calafat – 27.8°C (the second highest mean monthly value after the one registered at Caracal in 2012 – 27.9°C).

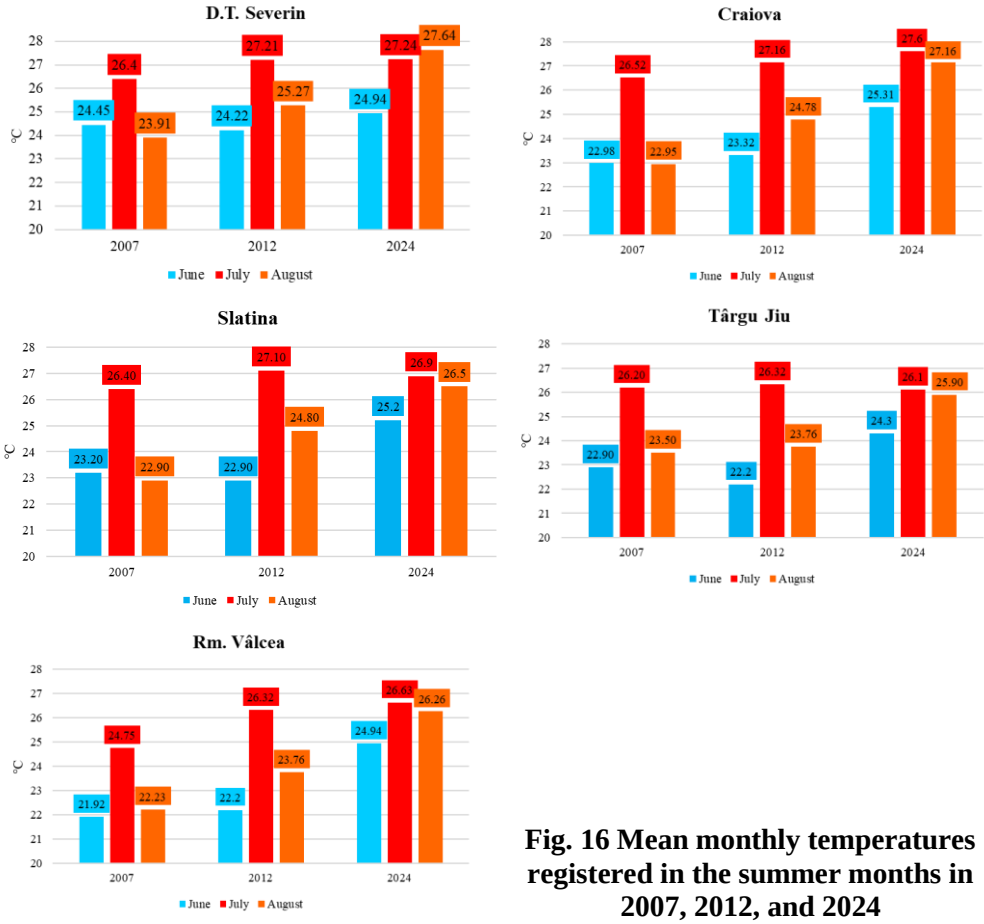


Fig. 16 Mean monthly temperatures registered in the summer months in 2007, 2012, and 2024

August 2024 stands for the warmest month on record with a mean value of 24.5°C at the country level and a positive deviation of 2.9°C (NMA, 2024c). In Oltenia, mean temperatures were higher than the ones registered in 2007 and 2012

at all the meteorological stations, deviations ranging between about +2°C and +4°C. There were five stations with mean values above 27°C – D.T. Severin, Calafat, Craiova, Caracal, Drăgășani and four above 26°C – Băilești, Slatina, Bâcleș, Rm. Vâlcea.

6. CONCLUSIONS

In Romania, the summer of 2024 is considered the warmest registered in the period 1901-2024, with a mean temperature of 24.2°C, which is 0.7°C more than the previous record corresponding to the summer of 2012. In Oltenia, it was also the hottest summer in terms of mean temperatures in the last six decades, average monthly temperatures exceeding 27°C in July and August in most of the plain area, and 26°C in the hilly extra-Carpathian area. June and August registered higher values compared to the ones from 2007 and 2012 at all meterological stations, in most of the cases marking new thermal records in terms of mean monthly temperature. Within the entire plain area and the eastern part of the Getic Piedmont, the mean temperature of the summer 2024 exceeded 26°C, the highest values corresponding to Caracal with 26.96°C and Calafat with 26.86°C. In the western sector of the piedmont and on the Jiu and the Olt Valleys in the Subcarpathian area values were between 25 and 26°C, while in the rest of the Subcarpahians they oscillated between 23 and 24°C. In the mountains, 17.23°C were registered at Parâng station and 21.1°C at Petroșani station.

There were **24** daily maximum temperatures **above 40°C**, mostly in July (the interval 14-17), when the heatwave reached its maximum intensity. In August, the heatwave lasted less (7 to 10 days) and there were only 4 cases of daily maximum temperatures ≥40°C, all at the stations located in the proximity of the Danube. At Calafat, Bechet, and Băilești there were six consecutive days (July 13-July 18) with maximum temperatures between 39.2°C and 40.6°C (four values above 40°C). The eastern part of Oltenia was also greatly affected, both Slatina and Rm. Vâlcea registering two days each with more than 40°C in the same interval. In fact, the highest value from this summer, 41.3°C was registered at Slatina.

Even if the heatwave from July 2024 was less intense compared to the one from July 2007, it lasted longer. Moreover, the heatwave registered in August amplified the problems at regional level as there was also an acute lack of precipitation during the entire summer.

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