

## HEATWAVES IN ROMANIA -FREQUENCY AND DURATION

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**ABSTRACT.** Heatwaves are recognized, although there is still no general acknowledged definition, as periods of unusually hot and dry or hot and humid weather, which occur gradually and cease in the same way, lasting at least 2 to 3 days with visible impact on human activities. Episodes characterized by heatwaves induce excessively hot weather compared to the local climatic specific features. The period with or without heatwaves is different from a region to another, depending on the particularities of each area. This climatological hazard can be described as an advection of tropical air mass which, compared to the climatological standards, leads to reaching large positive temperature deviations, that in some cases will set new thermal records. In the northern hemisphere, in the area of temperate latitudes, which includes Romania, the highest values of air temperature are generally recorded from mid-June to the end of August. Heatwaves in Romania are mainly generated by the advection of continental hot air masses from North Africa, leading to a stable stratification of the atmosphere from ground levels to more higher ones. The ridge of the North African anticyclone extends either over Central Europe or Central Eastern Europe, up to Romania, generating heatwaves for the first scenario in the western regions of our country, whereas or the second one outside the Carpathians, most frequently in the Romanian Plain. In Romania, the most frequent heatwaves, taken by duration in time are those between 2 and 5 days. while analysed in terms of intensity, stand out those during summer months (June to August).

**Keywords:** heatwave, hot weather, advection, daily maximum temperature

### 1. INTRODUCTION

The Intergovernmental Panel on Climate Change (IPCC 2007), in the evaluations conducted after 2000, confirmed the persistence of meteorological phenomena attesting to the warming of the Earth's climate, including the increased frequency of heatwaves. These climatic extreme, such as heatwaves, have a negative impact on the environment, cause significant economic damage and even human deaths. Recent studies in the literature provide solid evidence that the problem of global warming is

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certainly a serious one. Although characterized by notable barriers, the connection between climate change adaptation and disaster risk mitigation is significant and its effects are beginning to emerge (McBean and Ajibade 2009).

Even if surface temperature values are rising globally, warming is not uniform across continents (Jones 2001, Jones and Moberg 2003, Solomon et al. 2007, Kerr 2009, Nick et al 2009, Lorentzen 2014). The global average temperature has risen by about 0.85 Celsius degrees from 1880 to 2012 and will continue to rise so that by the end of the 21<sup>st</sup> century it will be 0.3 to 4.8 Celsius degrees higher, according to the IPCC's fifth assessment (Hartmann et al 2013). Regional and local particularities are crucial for regional and local variations in the climate system.

According to the guide published by the World Meteorological Organisation (WMO) in 2015, the heatwave or hot weather that continues in successive days (without the previous requirement of at least 5 days) represents a heatwave if it has the characteristics of a natural hazard, meaning that the excessively hot weather has negative effects on human life and way of living, on socio-economic activity in general, being possible to adversely affect even the infrastructure. Natural systems can also be severely affected by the impact of this phenomena, depending on the duration of the event.

Although there is still no universally valid definition of a heatwave, they are acknowledged as events of unusual hot and dry weather or hot and humid weather, which occur gradually and cease in the same way, with a duration of at least 2 to 3 consecutive days and a visible impact on human activities. Heatwaves depend on the climate of the analysed location, because the same weather conditions are perceived differently by the population living in one area or another. In some countries periods with certain temperature values can be characterized as severe weather events, while in others they are just normal weather pattern.

Therefore, heatwave events are periods of at least 2 to 3 consecutive days with excessively hot weather related to local climatic features. This natural hazard can be described as an advection of tropical air mass that leads to large positive temperature deviations and in some cases also to the establishment of new thermal records.

In the northern hemisphere, for the area of temperate latitudes, where Romania is included, the highest values of air temperature are generally recorded from mid-June to the end of August (Climate of Romania 2008).

Romania, because of its physical-geographical peculiarities, has a high degree of exposure and vulnerability in terms of the occurrence of various meteorological hazards. Due to the fact that the orographic feature of our country starts from the highest peaks of the Carpathians and ends at the lowest regions near the Black Sea, gradually passing through all landforms, a series of climatic characteristics develop (Dima et al 2016). Therefore, the mediated thermal regime for each region of the national territory is different. From another perspective, the way in which the weather changes or not from one day to the next one is influenced by the alternation, often at an accelerated pace, of the types of circulation and advection of specific air masses (such as tropical ones regarding heatwaves) and by changes in the thermo-

baric field at the synoptic scale set-out by the distribution and dominance of one of the main centres, both at ground level and higher in the troposphere.

Heatwaves in Romania are usually associated with the presence of a high atmospheric pressure field that lead to a stable stratification of the atmosphere levels and the advection of continental hot air masses from North Africa. Heatwaves appear in Romania in the western regions when the ridge of the North African anticyclone extends over Central Europe and outside the Carpathians, most frequently in the Romanian Plain, when it shifts over Central Eastern Europe.

Heatwaves in Romania are usually analysed according to the general warnings' thresholds: 32.5 °C, 35.0 °C, 37.5 °C and 39.0 °C (Croitoru et al 2018, Timu, 2010). Due to the complex physical-geographical characteristic of Romania, hot air masses responsible for the periods with unusual hot weather extend different from one region to another in Romania, and as a result, a heatwave event is more intense and has different impact in the north compared for example with the south of the country (Barbu et al 2014).

## **2. DATA AND METHODS**

### **2.1. Data used**

#### **2.1.1. Daily maximum temperature data**

The daily maximum temperature data from 1961 to 2017 were downloaded from the European Climate Assessment & Dataset (ECAD) open-source website (<https://www.ecad.eu/>) and some missing values were added from the Romanian National Meteorological Administration database. The analysis for this study includes data from the warm season (April to October) for 21 meteorological stations from each region of Romania: Arad, Caransebeş, Deva, Sibiu, Miercurea Ciuc, Cluj-Napoca, Ocna Şugatag, Botoşani, Iaşi, Bacău, Galaţi, Tulcea, Sulina, Constanţa, Buzău, Bucureşti-Băneasa, Călăraşi, Roşiori de Vede, Râmnicu Vâlcea, Craiova şi Drobeta Turnu Severin.

### **2.2. Methods**

Data processing was conducted using Microsoft Excel. The main work sheet is a table with 9 columns: year, month, day, daily maximum temperature, the multiannual average of the daily maximum temperature (average between daily maximum temperature from 1961 to 2017), deviation (difference between the daily maximum temperature and its multiannual average), YES/NO (if the average is higher than 5 Celsius degrees appears an YES in the cell, otherwise NO), COUNT 1 (an if function searches for the YES cells and the first one encountered gets value 1 and in case of a second consecutive one value 2 appears and so on) and COUNT 2 (an if function searches for the maximum consecutives from COUNT1 and displays it, such as 1, 2, 3 or more). A pivot table was used in order to summarize the number of episodes with specific lengths and create the table behind each chart.

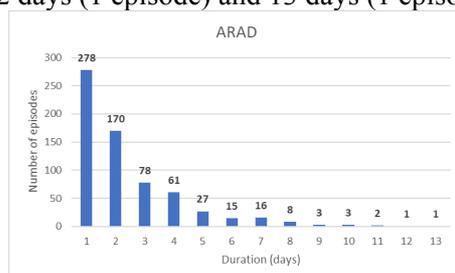
In conclusion, for each meteorological station, using the formulas presented above, it was possible to easily identify the number of episodes with excessive hot weather, starting from 1 day to 2, 3, 4 consecutive days and so on.

### 3. RESULTS AND DISCUSSIONS

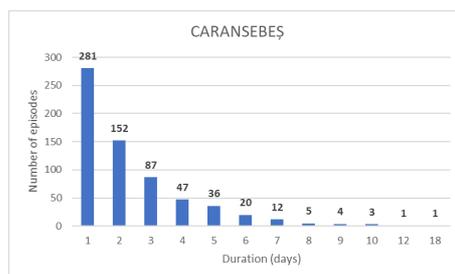
Between 1961 and 2017 for Arad meteorological station the following were identified:

-278 days when the daily maximum temperature exceeded the multiannual average of the daily maximum temperature with 5 °C;

-heatwaves with a duration of 2 days (170 episodes), 3 days (78 de episodes), 4 days (61 de episodes), 5 days (27 de episodes), 6 days (15 episodes), 7 days (16 episodes), 8 days (8 episodes), 9 days (3 episodes), 10 days (3 episodes), 11 days (2 episodes), 12 days (1 episode) and 13 days (1 episode).



**Fig. 1. – Duration of heatwaves episodes at Arad meteo station**

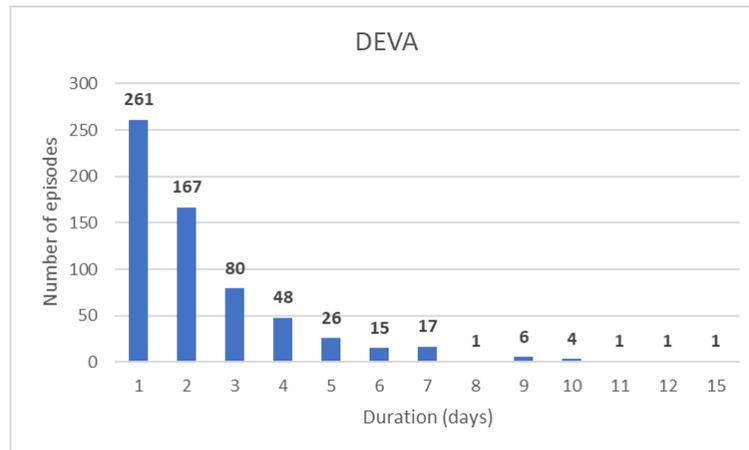


**Fig. 2. – Duration of heatwaves episodes at Caransebeș meteo station**

Between 1961 and 2017 for Caransebeș meteorological station the following were identified:

-281 days when the daily maximum temperature exceeded the multiannual average of the daily maximum temperature with 5 °C;

-heatwaves with a duration of 2 days (152 de episodes), 3 days (87 de episodes), 4 days (47 de episodes), 5 days (36 de episodes), 6 days (20 de episodes), 7 days (12 episodes), 8 days (5 episodes), 9 days (4 episodes), 10 days (3 episodes), 12 days (1 episode) and 18 days (1 episode).

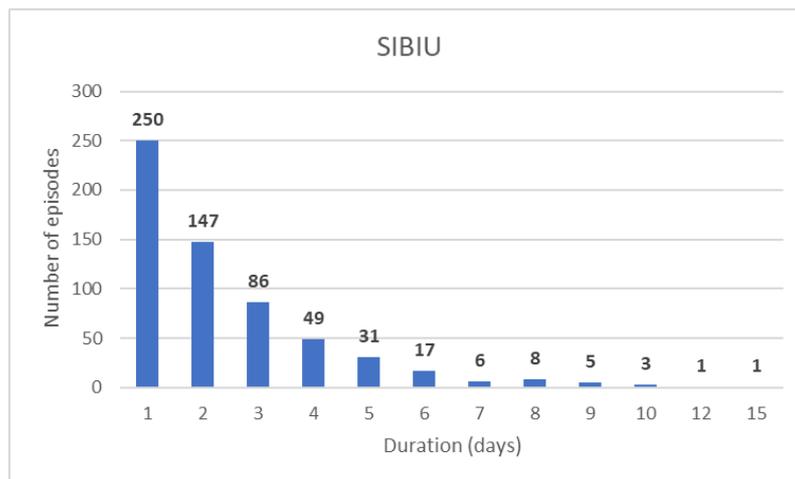


**Fig. 3. – Duration of heatwaves episodes at Deva meteo station**

Between 1961 and 2017 for Deva meteorological station the following were identified:

-261 days when the daily maximum temperature exceeded the multiannual average of the daily maximum temperature with 5 °C;

-heatwaves with a duration of 2 days (167 de episodes), 3 days (80 de episodes), 4 days (48 de episodes), 5 days (26 de episodes), 6 days (15 episodes), 7 days (17 episodes), 8 days (1 episode), 9 days (6 episodes), 10 days (4 episodes), 11 days (1 episode), 12 days (1 episode) and 15 days (1 episode).

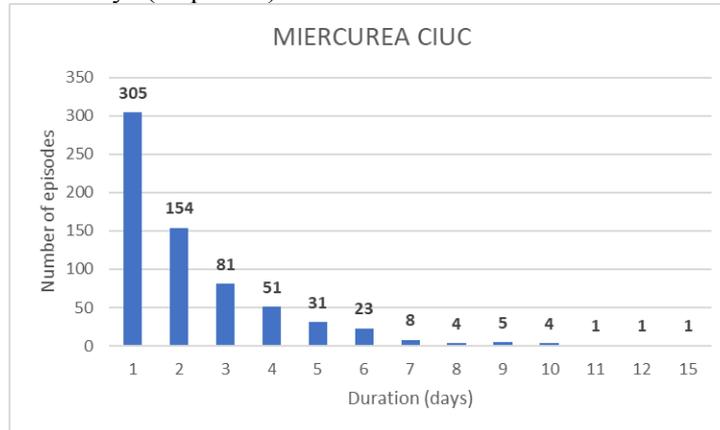


**Fig. 4. – Duration of heatwaves episodes at Sibiu meteo station**

Between 1961 and 2017 for Sibiu meteorological station the following were identified:

-250 days when the daily maximum temperature exceeded the multiannual average of the daily maximum temperature with 5 °C;

-heatwaves with a duration of 2 days (147 de episodes), 3 days (86 de episodes), 4 days (49 de episodes), 5 days (31 de episodes), 6 days (17 de episodes), 7 days (6 episodes), 8 days (8 episodes), 9 days (5 episodes), 10 days (3 episodes), 12 days (1 episode) and 15 days (1 episode).

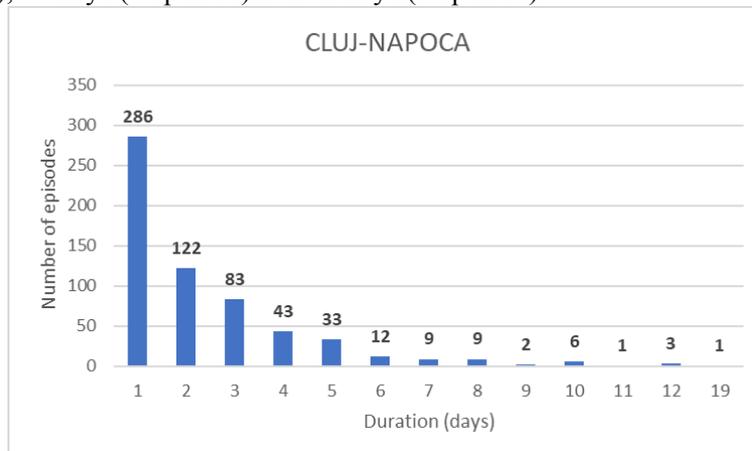


**Fig. 5. – Duration of heatwaves episodes at Miercurea Ciuc meteo station**

Between 1961 and 2017 for Sibiu meteorological station the following were identified:

-305 days when the daily maximum temperature exceeded the multiannual average of the daily maximum temperature with 5 °C;

-heatwaves with a duration of 2 days (154 de episodes), 3 days (81 de episodes), 4 days (51 de episodes), 5 days (31 de episodes), 6 days (23 episodes), 7 days (8 episodes), 8 days (4 episodes), 9 days (5 episodes), 10 days (4 episodes), 11 days (1 episode), 12 days (1 episode) and 15 days (1 episode).

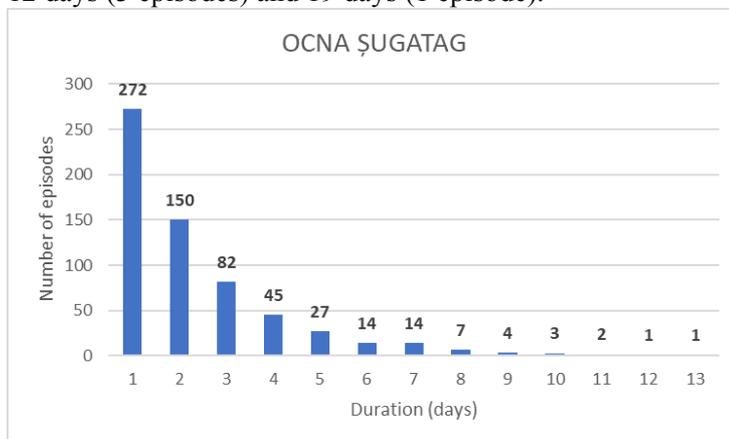


**Fig. 6. – Duration of heatwaves episodes at Cluj-Napoca meteo station**

Between 1961 and 2017 for Cluj-Napoca meteorological station the following were identified:

-286 days when the daily maximum temperature exceeded the multiannual average of the daily maximum temperature with 5 °C;

-heatwaves with a duration of 2 days (122 de episodes), 3 days (83 de episodes), 4 days (43 de episodes), 5 days (33 de episodes), 6 days (12 de episodes), 7 days (9 episodes), 8 days (9 episodes), 9 days (2 episodes), 10 days (6 episodes), 11 days (1 episode), 12 days (3 episodes) and 19 days (1 episode).

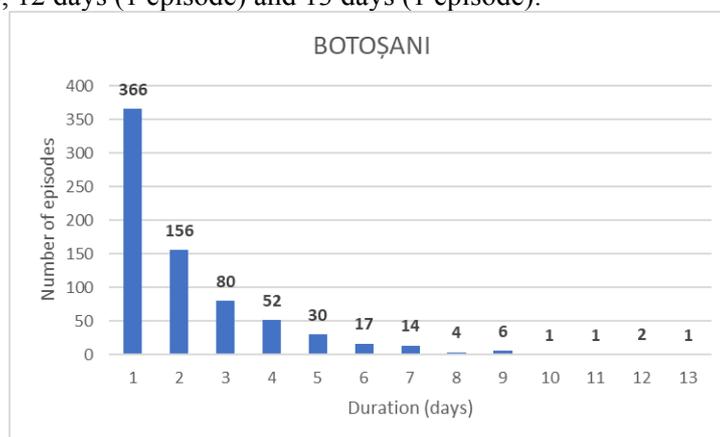


**Fig. 7. – Duration of heatwaves episodes at Ocna Șugatag meteo station**

Between 1961 and 2017 for Ocna Șugatag meteorological station the following were identified:

-272 days when the daily maximum temperature exceeded the multiannual average of the daily maximum temperature with 5 °C;

-heatwaves with a duration of 2 days (150 de episodes), 3 days (82 de episodes), 4 days (45 de episodes), 5 days (27 de episodes), 6 days (14 episodes), 7 days (14 episodes), 8 days (7 episodes), 9 days (4 episodes), 10 days (3 episodes), 11 days (2 episodes), 12 days (1 episode) and 13 days (1 episode).

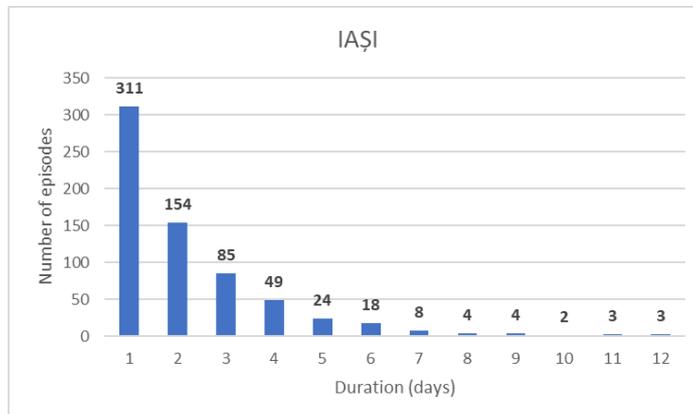


**Fig. 8. – Duration of heatwaves episodes at Botoșani meteo station**

Between 1961 and 2017 for Botoșani meteorological station the following were identified:

-366 days when the daily maximum temperature exceeded the multiannual average of the daily maximum temperature with 5 °C;

-heatwaves with a duration of 2 days (156 de episodes), 3 days (80 de episodes), 4 days (52 de episodes), 5 days (52 de episodes), 6 days (17 episodes), 7 days (14 episodes), 8 days (4 episodes), 9 days (6 episodes), 10 days (1 episode), 11 days (1 episod), 12 days (2 episodes) and 13 days (1 episode).

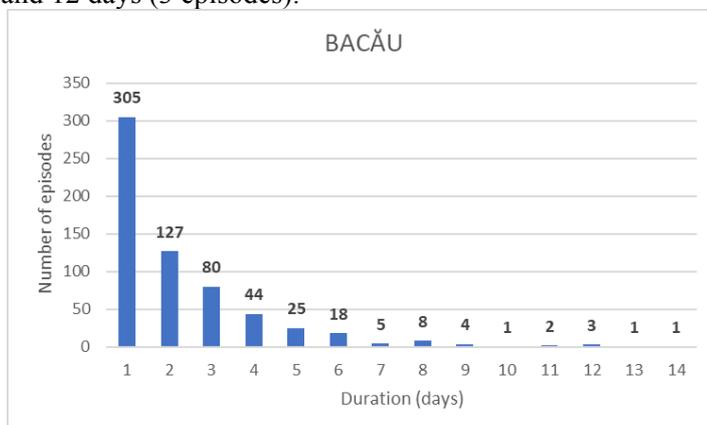


**Fig. 9. – Duration of heatwaves episodes at Iași meteo station**

Between 1961 and 2017 for Iași meteorological station the following were identified:

-311 days when the daily maximum temperature exceeded the multiannual average of the daily maximum temperature with 5 °C;

-heatwaves with a duration of 2 days (154 de episodes), 3 days (85 de episodes), 4 days (49 de episodes), 5 days (24 de episodes), 6 days (18 episodes), 7 days (8 episodes), 8 days (4 episodes), 9 days (4 episodes), 10 days (2 episodes), 11 days (3 episodes) and 12 days (3 episodes).

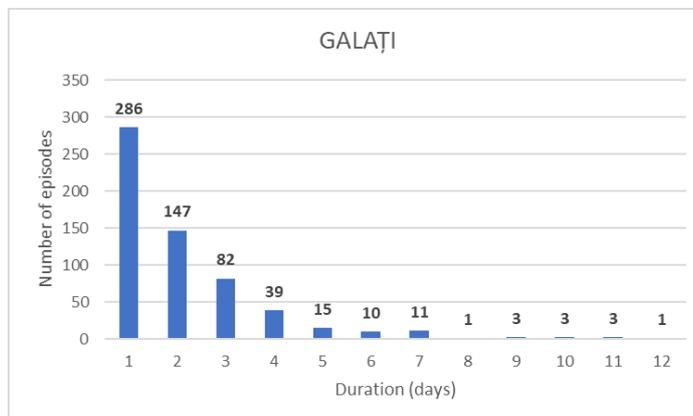


**Fig. 10. – Duration of heatwaves episodes at Bacău meteo station**

Between 1961 and 2017 for Bacău meteorological station the following were identified:

-305 days when the daily maximum temperature exceeded the multiannual average of the daily maximum temperature with 5 °C;

-heatwaves with a duration of 2 days (127 de episodes), 3 days (80 de episodes), 4 days (44 de episodes), 5 days (25 de episodes), 6 days (18 de episodes), 7 days (5 episodes), 8 days (8 episodes), 9 days (4 episodes), 10 days (1 episode), 11 days (2 episodes), 12 days (3 episodes), 13 days (1 episode) and 14 days (1 episode).

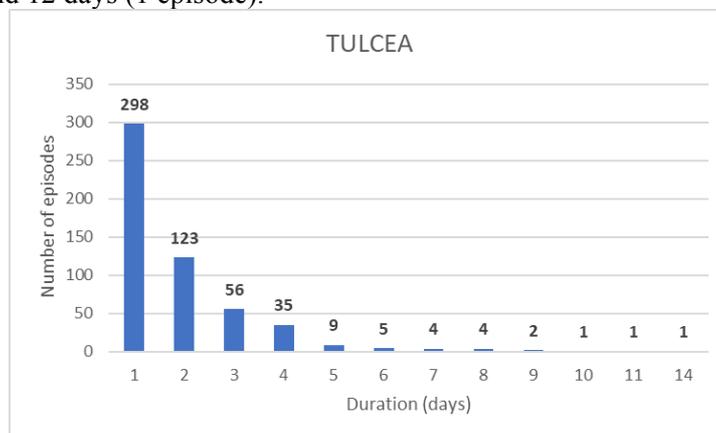


**Fig. 11. – Duration of heatwaves episodes at Galați meteo station**

Between 1961 and 2017 for Galați meteorological station the following were identified:

-286 days when the daily maximum temperature exceeded the multiannual average of the daily maximum temperature with 5 °C;

-heatwaves with a duration of 2 days (147 de episodes), 3 days (82 de episodes), 4 days (39 de episodes), 5 days (15 de episodes), 6 days (10 episodes), 7 days (11 episodes), 8 days (1 episode), 9 days (3 episodes), 10 days (3 episodes), 11 days (3 episodes) and 12 days (1 episode).

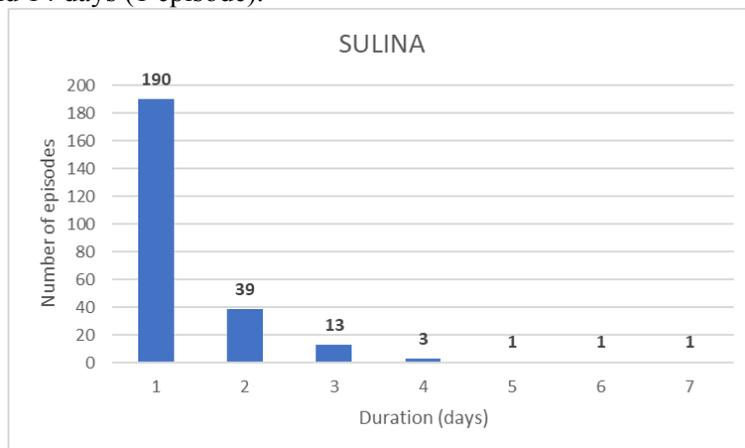


**Fig. 12. – Duration of heatwaves episodes at Tulcea meteo station**

Between 1961 and 2017 for Tulcea meteorological station the following were identified:

-298 days when the daily maximum temperature exceeded the multiannual average of the daily maximum temperature with 5 °C;

-heatwaves with a duration of 2 days (123 de episodes), 3 days (56 de episodes), 4 days (35 de episodes), 5 days (9 episodes), 6 days (5 episodes), 7 days (4 episodes), 8 days (4 episodes), 9 days (2 episodes), 10 days (1 episode), 11 days (1 episode) and 14 days (1 episode).

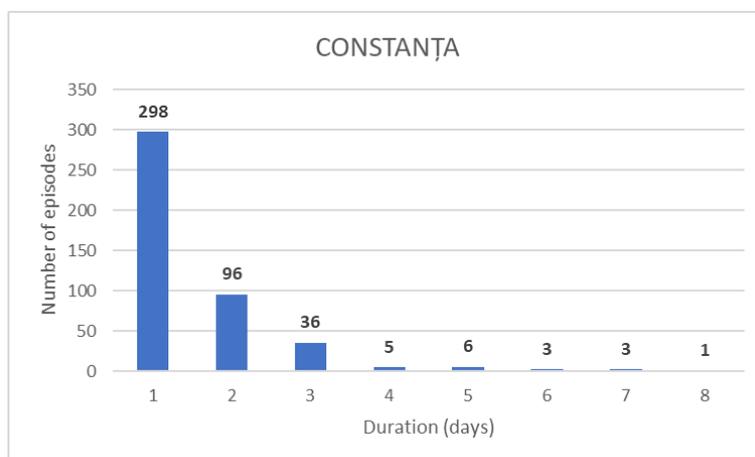


**Fig. 13. – Duration of heatwaves episodes at Sulina meteo station**

Between 1961 and 2017 for Sulina meteorological station the following were identified:

-190 days when the daily maximum temperature exceeded the multiannual average of the daily maximum temperature with 5 °C;

-heatwaves with a duration of 2 days (39 de episodes), 3 days (13 episodes), 4 days (3 episodes), 5 days (1 episode), 6 days (1 episode) and 7 days (1 episode).

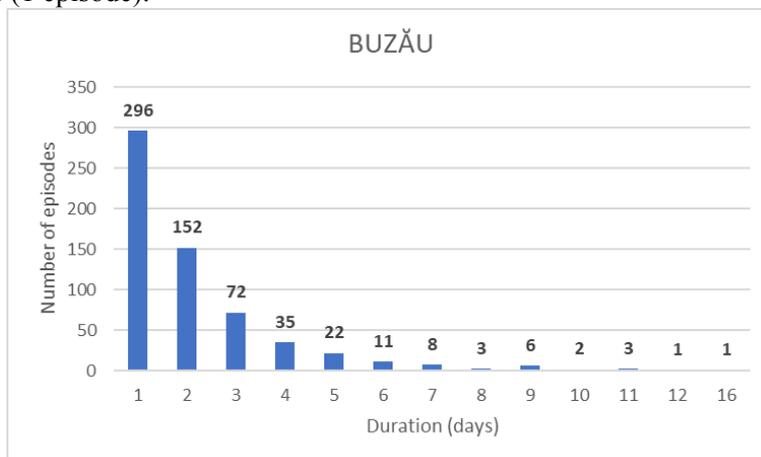


**Fig. 14. – Duration of heatwaves episodes at Constanța meteo station**

Between 1961 and 2017 for Constanța meteorological station the following were identified:

-298 days when the daily maximum temperature exceeded the multiannual average of the daily maximum temperature with 5 °C;

-heatwaves with a duration of 2 days (96 de episodes), 3 days (36 de episodes), 4 days (5 episodes), 5 days (6 episodes), 6 days (3 episodes), 7 days (3 episodes) and 8 days (1 episode).

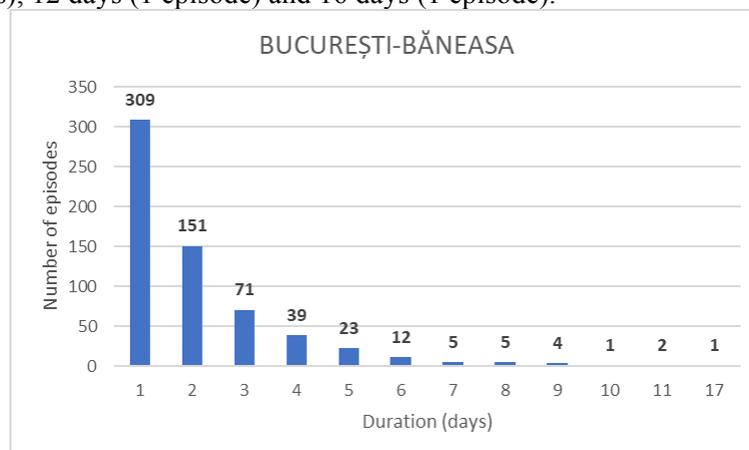


**Fig. 15. – Duration of heatwaves episodes at Buzău meteo station**

Between 1961 and 2017 for Buzău meteorological station the following were identified:

-296 days when the daily maximum temperature exceeded the multiannual average of the daily maximum temperature with 5 °C;

-heatwaves with a duration of 2 days (152 de episodes), 3 days (72 de episodes), 4 days (35 de episodes), 5 days (22 de episodes), 6 days (11 episodes), 7 days (8 episodes), 8 days (3 episodes), 9 days (6 episodes), 10 days (2 episodes), 11 days (3 episodes), 12 days (1 episode) and 16 days (1 episode).

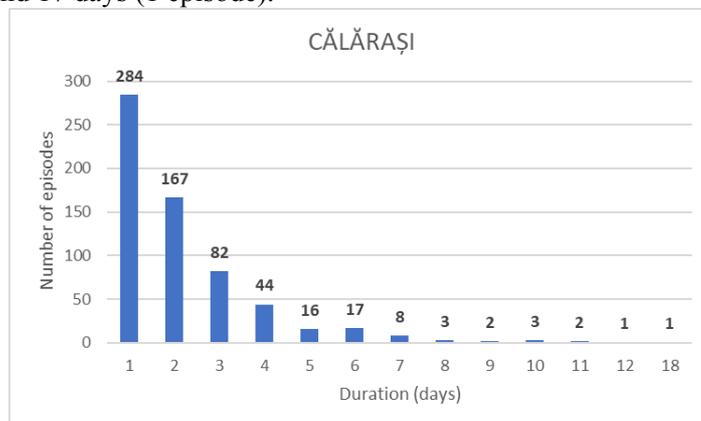


**Fig. 16. – Duration of heatwaves episodes at București Băneasa meteo station**

Between 1961 and 2017 for București Băneasa meteorological station the following were identified:

-309 days when the daily maximum temperature exceeded the multiannual average of the daily maximum temperature with 5 °C;

-heatwaves with a duration of 2 days (151 de episodes), 3 days (71 de episodes), 4 days (39 de episodes), 5 days (23 de episodes), 6 days (12 episodes), 7 days (5 episodes), 8 days (5 episodes), 9 days (4 episodes), 10 days (1 episode), 11 days (2 episodes) and 17 days (1 episode).

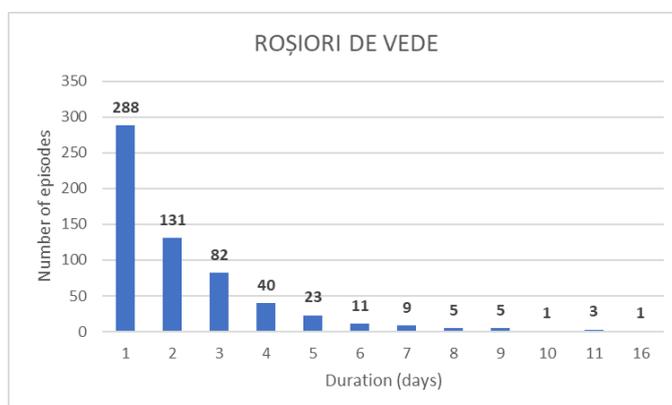


**Fig. 17. – Duration of heatwaves episodes at Călărași meteo station**

Between 1961 and 2017 for Călărași meteorological station the following were identified:

-284 days when the daily maximum temperature exceeded the multiannual average of the daily maximum temperature with 5 °C;

-heatwaves with a duration of 2 days (167 de episodes), 3 days (82 de episodes), 4 days (44 de episodes), 5 days (16 episodes), 6 days (17 episodes), 7 days (8 episodes), 8 days (3 episodes), 9 days (2 episodes), 10 days (3 episodes), 11 days (2 episodes), 12 days (1 episode) and 18 days (1 episode).

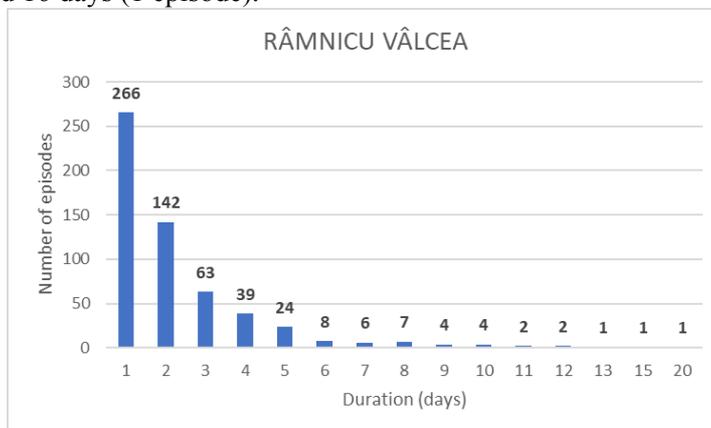


**Fig. 18. – Duration of heatwaves episodes at Roșiori de Vede meteo station**

Between 1961 and 2017 for Roşiori de Vede meteorological station the following were identified:

-288 days when the daily maximum temperature exceeded the multiannual average of the daily maximum temperature with 5 °C;

-heatwaves with a duration of 2 days (131 de episodes), 3 days (82 de episodes), 4 days (40 de episodes), 5 days (23 de episodes), 6 days (11 episodes), 7 days (9 episodes), 8 days (5 episodes), 9 days (5 episodes), 10 days (1 episode), 11 days (3 episodes) and 16 days (1 episode).

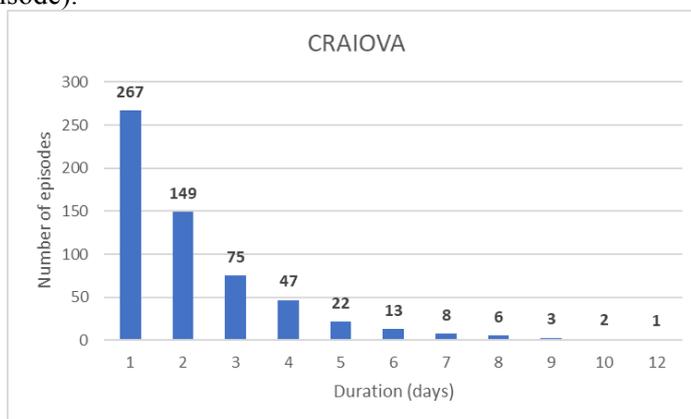


**Fig. 19. – Duration of heatwaves episodes at Râmnicu Vâlcea meteo station**

Between 1961 and 2017 for Râmnicu Vâlcea meteorological station the following were identified:

-266 days when the daily maximum temperature exceeded the multiannual average of the daily maximum temperature with 5 °C;

-heatwaves with a duration of 2 days (142 de episodes), 3 days (63 de episodes), 4 days (39 de episodes), 5 days (24 de episodes), 6 days (8 episodes), 7 days (6 episodes), 8 days (7 episodes), 9 days (4 episodes), 10 days (4 episodes), 11 days (2 episodes), 12 days (2 episodes), 13 days (1 episode), 15 days (1 episode) and 20 de days (1 episode).

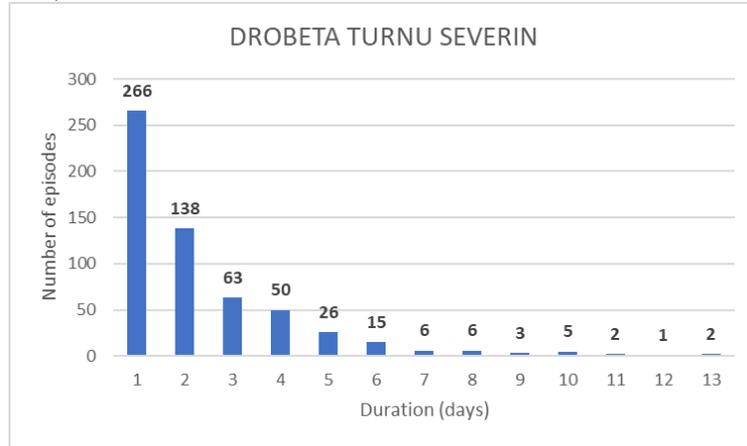


**Fig. 20. – Duration of heatwaves episodes at Craiova meteo station**

Between 1961 and 2017 for Craiova meteorological station the following were identified:

-267 days when the daily maximum temperature exceeded the multiannual average of the daily maximum temperature with 5 °C;

-heatwaves with a duration of 2 days (149 de episodes), 3 days (75 de episodes), 4 days (47 de episodes), 5 days (22 de episodes), 6 days (13 episodes), 7 days (8 episodes), 8 days (6 episodes), 9 days (3 episodes), 10 days (2 episodes) and 12 days (1 episode).

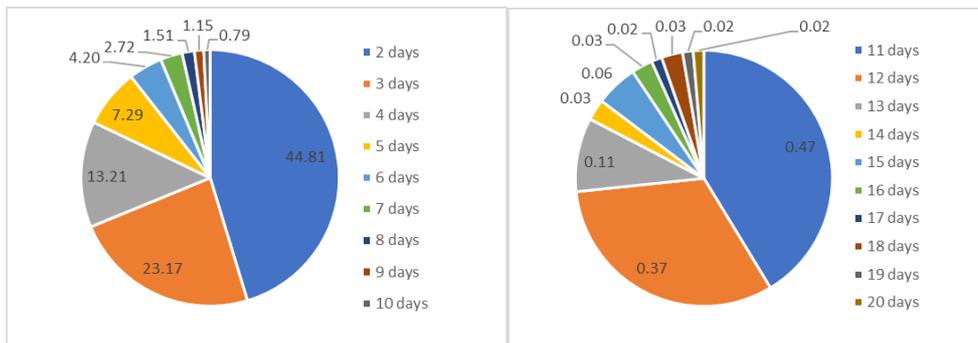


**Fig. 21. – Duration of heatwaves episodes at Drobeta Turnu Severin meteo station**

Between 1961 and 2017 for Drobeta Turnu Severin meteo station the following were identified:

-266 days when the daily maximum temperature exceeded the multiannual average of the daily maximum temperature with 5 °C;

-heatwaves with a duration of 2 days (138 de episodes), 3 days (63 de episodes), 4 days (50 de episodes), 5 days (26 de episodes), 6 days (15 episodes), 7 days (6 episodes), 8 days (6 episodes), 9 days (3 episodes), 10 days (5 episodes), 11 days (2 episodes), 12 days (1 episode) and 13 days (1 episode).



**Fig. 22. – Frequency (%) of heatwaves episodes taken by duration**

In fig. 22. the pie chart summarizes the frequency of heatwaves episodes taken by duration. From a total of 6547 heatwaves episodes with duration between 2 to 20 days, the most frequent ones are the following: 44.81% for 2 days events, 23.17% for 3 days events, 13.21% for 4 days events, 7.29% of 5 days events, 4.20% for 6 days events, 2.72% for 7 days events, 1.51% for 8 days events, 1.15% for 9 days events and under 1% for 1- to 20 days events.

#### 4. CONCLUSIONS

Heatwaves in Romania generally occur as a result of the advection of tropical hot air masses of continental origin from the north of the African continent, when the ridge of the North African anticyclone extends towards Europe. They appear all over Romanian territory with different intensity from one region to another due to characteristic features of the local climate.

The most frequent heatwaves, as shown by the analyzed data, are those with a duration of 2 to 5 days, and there are some exceptional situations when a heatwave lasts up to 18-20 days.

Periods with extreme weather, such as intervals with heatwaves, most intense during the summer months, have a negative impact on human life and can disrupt socio-economic activities.

Heatwaves represent a meteorological hazard of unusually hot weather, that for Romania has a high probability of occurrence, more intense from June to August.

#### ACKNOWLEDGEMENTS

Data sources:

- European Climate Assessment & Dataset (ECAD) open-source website (<https://www.ecad.eu/>);
- Romanian National Meteorological Administration database.

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    - b. <https://www.ecad.eu/>