

THE EVOLUTION OF THE MAXIMUM EXTREME TEMPERATURES IN THE AREA OF THE ROMANIAN BLACK SEA COAST DURING 1961 – 2020

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Abstract. The present study investigates the trends in the monthly, seasonal and annual regime of maximum temperatures in the Romanian Black Sea coast area over the last 60 years (1961-2020), using the monthly and annual maximum temperature data provided by five meteorological stations (i.e. Sulina, Sf. Gheorghe-Delta, Gura Portiței, Constanța, Mangalia). Three CLIMPACT extreme temperature indices (i.e. monthly and the annual average of maximum temperatures - TXm, the lowest monthly and annual value of the maximum temperature -TXn, and the highest monthly and annual value of the maximum temperature -TXx) and trends analysis methods (i.e. Mann-Kendall test, Sen's slope estimator) have been used in the study. The targeted region is under a visible and generalized warming, especially in winter and summer. The estimated warming trends are among the highest at national level. At some stations (i.e. Sulina) spring also emerges as a significant warming season. The highest warming rate is up to 5°C (e.g. Constanța). The observed trends could contribute to an improved understanding for urging adaptation actions in some key sensitive economic sectors directly affected by the recent climate warming (e.g. health, tourism, transport, biodiversity).

Keywords: Black Sea coast, maximum temperatures, trends, historical records

1. INTRODUCTION

The ongoing warming is well reflected by a growing occurrence of high temperature extremes (i.e. hot days, hot nights, heat waves), frequently associated with extreme heat stress and lack of precipitation. Observational records in Romania, between 1901 and 2020, suggest that the average annual temperature increased by more than 1°C. However, the regional effects of the global warming are diversified by several local factors including the proximity of the Black Sea or the presence of the Danube River. In winter and summer, the temperature increases are highest, while in autumn the trends are more diminished. Generally, the southern, western and eastern lowlands emerge as "hotspot" regions of Romania (Bojariu et al, 2022).

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The paper provides an updated analysis on the climatology, variability and observed trends (1961-2020) in the monthly, seasonal and annual regime of maximum temperatures. The research objectives of the study are to investigate the spatial distribution of: (1) maximum temperatures and associated historical records, and (2) observed monthly, seasonal and annual trends in maximum temperature and associated extremes.

2. DATA

The study is based on monthly and annual maximum temperatures from five meteorological stations on the Romanian Black Sea coast (Sulina, Sf. Gheorghe-Delta, Gura Portiței, Constanța and Mangalia), covering the period 1961-2020 and an elevation range of 1-13 m (Fig. 1). The selection includes Sulina station which was the first meteorological station established on the territory of Romania in 1859 within the framework of the Danube Commission. Tulcea, Sulina and Constanța meteorological stations are included in the international network Regional Basic Synoptic Network, whereas the latter two are included in the international Regional Basic Climatological Network. All selected stations are automatic. They are considered representative for the study, having continuous records since 1961 and locations which reflect the diversity of physical-geographical conditions within the study area: northern littoral area with deltaic climate and low urbanisation area (Sf. Gheorghe-Delta and Gura Portiței) and southern littoral area with a urban-coastal climate (Constanța and Mangalia). According to Raliță (2005), most of the selected weather stations have a degree of obstruction less than 6°, characteristic for clear or medium obstructed meteorological platform.

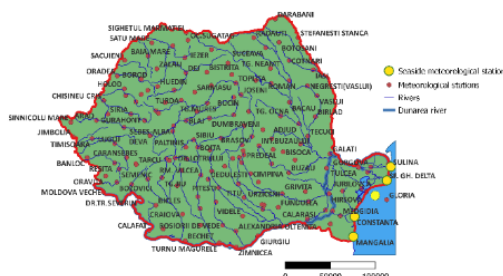


Fig.1. Location of the meteorological stations used in study

3. METHODOLOGY

The study uses three extreme temperature indices defined in the CLIMPACT project² (i.e. monthly and the annual average of maximum temperatures - TXm, the lowest monthly and annual value of the maximum temperature -TXn, and the highest monthly and annual value of the maximum temperature-TXx). The local significance of trend has been analyzed with the nonparametric Mann-Kendall (MK) test and the Sen trend slope estimator (expressed in °C/period). The MK test is a rank-based procedure, especially suitable for non-normally distributed data, data

²Climpact (climpact-sci.org) accessed 05.12.2022

containing outliers and non-linear trends. The cut-of statistical significance level in this study is 95% ($p\text{-value} < 0.05$). The trend analyses have been performed at monthly, seasonal and annual levels.

4. RESULTS AND DISCUSSION

In the period 1961-2020 in Romania there is a visible signal of climate warming, statistically significant, generally more pronounced during the day, affecting all regions of development.³ Analysing the data recorded at the analysed stations where the mean values of the annual maximum temperatures are presented, it is observed that the lowest values were recorded at the meteorological station Gura Portiței, with a value of 6.74 °C in 1985, and the highest at Constanța 18.31°C in 2019, Sfântu Gheorghe-Delta and Mangalia, with mean values of the monthly extreme maximum temperatures 17.72°C and 17.39 °C respectively also in 2020 (Fig. 2).

The difference between the mean minimum extreme maximum temperatures between Gura Portiței station and the other analyzed stations is significant, with a minimum of 5.43°C compared to Sulina meteorological station and a maximum of 6.84°C compared to Constanța station. As regards the evolution of the monthly extreme maximum temperature averages, a climatic signal of warming is observed, with an average TXm value at most of the meteorological stations analysed with values around 15 °C. The highest value of the monthly average of TXm minimums was recorded at Sf.

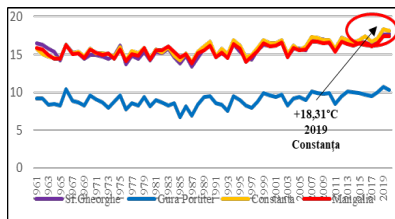


Fig. 1. Annual average TXm in the period 1961-2020 at the meteorological stations used in study

Gheorghe-Delta in July, being 24.30°C, with a minimum difference of 0.46°C compared to the Constanța station which recorded the maximum value of 23.84°C also in July and a maximum of 7.60°C, the value at Gura Portiței being 16.70 °C also in July. The other recorded highs of TXm lows were: Sulina 22.37°C, Constanța 23.84°C and Mangalia 21.84°C, all recorded in August. Analyzing the average monthly maximum TXm, the highest values were recorded at the weather station Sf. Gheorghe-Delta in August, with a value of 31.00°C, the maximum difference being 7.75°C compared to the maximum at the station Gura Portiței of 23.25°C. The other maximum TXm recorded were: Sulina 29.15°C, Constanța 30.53°C and Mangalia 29.65°C, all recorded in August.

The lowest average maximum value was recorded at the Gura Portiței station in January, being 1.96 °C, the other stations recording values around 10°C in the same month of January, with a minimum temperature difference between Gura Portiței and Sulina of 7.09°C and a maximum difference between Gura Portiței and Constanța of 9.31°C. The evolution of the average minimum and maximum TXm at the analysed meteorological stations in the Black Sea coastal area of the National

³RO-ADAPT- National Strategy on Adaptation to Climate Change for the period 2022-2030 with a view to)

Meteorological Administration network were shown in Fig. 3. Both, the average of minimums and maximums recorded the lowest values at the Gura Portiței station, while the average of all the other maximums and minimums recorded values with almost similar evolution.

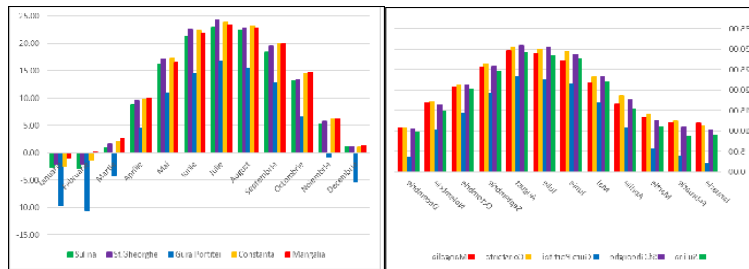


Fig. 2. Average monthly minimum (left) and maximum (right) TXm in the period 1961-2020 at the meteorological stations of the NMA network in the Black Sea coastal area

As regards the seasonal analysis of TXm evolution, it can be observed that the highest variations of monthly TXm averages are observed in the spring season and the lowest variations are observed in the summer. The lowest monthly TXm averages are recorded in all 4 seasons at Gura Portiței station, while the values at all other meteorological stations (Sulina, Sf. Gheorghe-Delta, Constanta and Mangalia) have values close to, much higher than those at Gura Portiței station (Fig. 4).

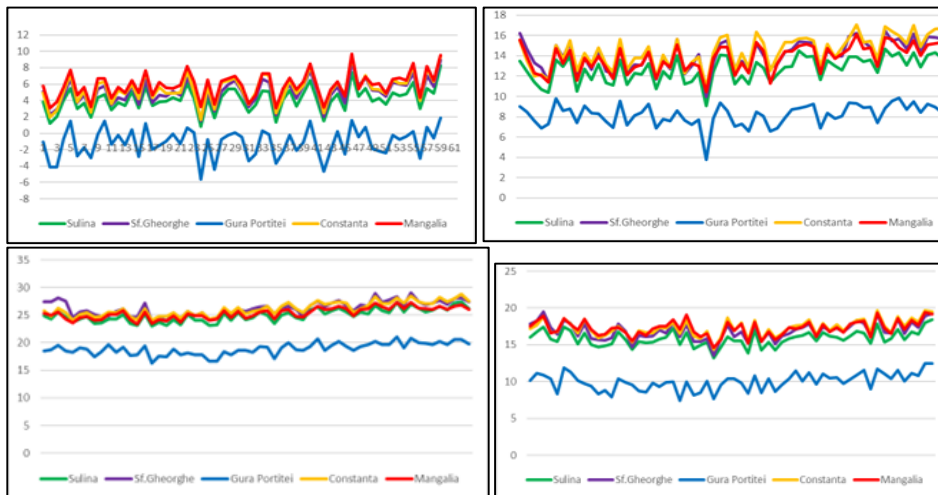


Fig. 4. Seasonal evolution of TXm in the period 1961 - 2020 at the meteorological stations used in study

As regards the second indicator analysed, namely TXn - minimum aily maximum temperatures, unlike TXm, where large variations in mean values are observed, the variations in minimum temperatures are quite small. Analyzing the observed that their amplitude is very small and varies as values between a minimum 5.94°C in 1987 at Gura Portiței station and a maximum 11.29°C at Sf. Gheorghe-Delta in 2021. In the analyzed data set, it is observed that

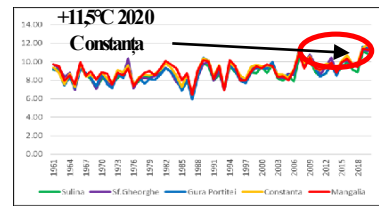


Fig. 5. Annual average TXn in the period 1961-2020 at the meteorological stations used in study

1987 was the coldest year, with values of TXn ranging between 5.94°C at Gura Portiței station and 6.51°C at Constanța station. The warmest year in the analysed data set was 2020, with minimum average TXn values around 11°C, with a minimum of 10.82°C and a maximum of 11.95°C at the Constanța station. Analyzing the mean monthly TXn maxima in the period 1961 - 2020 at the meteorological stations, a maximum value of 28.10°C is observed at the Gura Portiței station in August, with a temperature variation ranging from a minimum of 0.20°C at the Constanța station to a maximum of 2.20°C at the Sulina station. The maximum TXn recorded were: Sulina 25.90°C in July, 27.60°C at Sf. Gheorghe-Delta station in August, Constanța 27.90°C also in August and Mangalia 26.20°C in July. The minimum value was recorded in January, with a minimum of 2.30°C at Sf. Gheorghe-Delta station, with small differences from Sulina and Gura Portiței weather stations, with a maximum in January of 3.90°C at Mangalia station, with a difference of 1.60°C (Fig. 5). Analyzing the average of monthly TXn minimums in the period 1961 - 2020 at the meteorological stations, a minimum value of -12.70°C is observed at Sulina station in January, with close values at the other stations in the same month of January, with very small differences of less than 1°C, while the maximum value of TXn averages was recorded at Mangalia station in July with a value of 18.30°C, with a maximum difference of 2.30°C compared to Sulina and Gura Portiței stations and a minimum of 1°C compared to Constanța station. The other recorded values of the average minimum TXn at the other stations were as follows: Sf. Gheorghe-Delta -12°C, Gura Portiței -12.60°C, Constanța -12.40°C and Mangalia -12.30°C, all recorded in January. Analysing the maximum values of the minimum TXn, it is observed that the highest value was recorded in Mangalia, being 18.30°C in July, followed by 17.50°C in Sulina in August, Constanța 17.30°C in July, Sf. Gheorghe-Delta 17.20°C in August, the maximum minimum in Gura Portiței being 16.89°C also in August (Fig 6.).

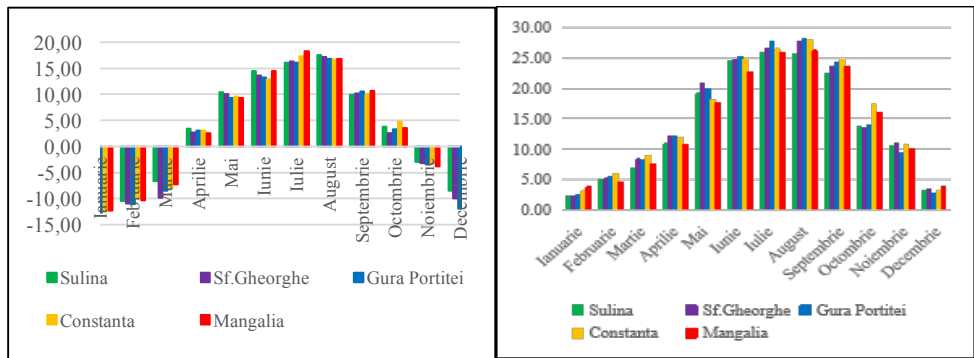


Fig. 6. Average monthly highs (left) and monthly lows (right) TXn in the period 1961 - 2020 at the meteorological stations of the NMA network in the Black Sea coastal area

Unlike TXm where the average minimum monthly values were recorded at the Gura Portiței meteorological station, in the case of the average minimum TXn the same trend is no longer maintained, observing that they have close values at all the stations analyzed, with maximum minimum averages in August and not July as in TXm. Analysing the mean TXn temperatures by seasons, it can be observed that there are no large temperature variations at the analysed stations in the winter season, these varying with small values, mainly negative, with only a few positive records at Mangalia and Sulina stations (Fig. 7).

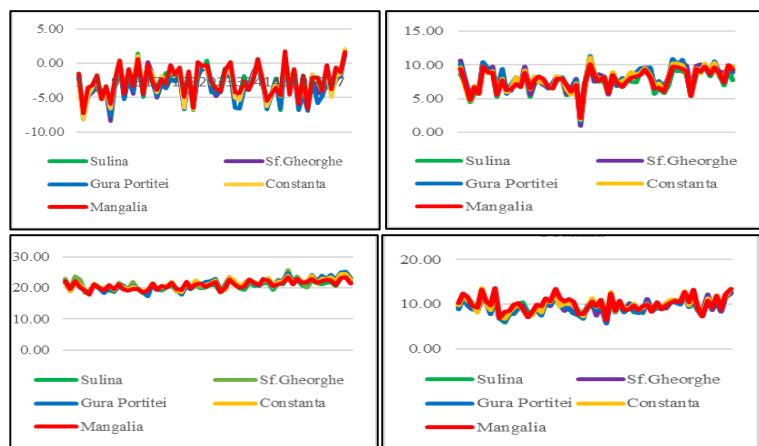
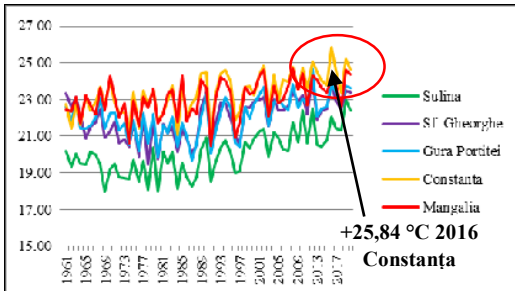


Fig. 7. Seasonal evolution of TXn in the period 1961 - 2020 at the meteorological stations used in study (winter-spring up, summer and autumn down)

In spring, larger variations are observed than in the winter season, with a minimum of 0.97°C at the Sf. Gheorghe-Delta station in 1987 and a maximum in 1989 of 11.33°C at the Gura Portiței station. In summer, the variations of the minimums of the TXn averages are very small, as in the winter season, while in the autumn much larger oscillations are observed, with a minimum of 5.70°C at the Sf. Gheorghe-Delta in 1994 and a maximum of 12.10°C in 1970 also at Sf. Gheorghe-

Delta. As for the maximum annual maximum temperatures (TXx). Analyzing the annual maximum temperatures at all stations, it can be seen that the lowest values of the annual maximums were recorded at Sulina station during the whole time interval analyzed 1961-2020, while the highest values of the maximums were recorded in turn at Constanța and Mangalia stations.

The TXx maximum at Mangalia station was 24.69°C in 2008. The TXx values recorded at Sf. Gheorghe-Delta and Gura Portiței stations were in the average values range, with a maximum of 24.26°C in 2012 at Sf. Gheorghe-Delta and 24.69°C, with an average value equal to that at Mangalia station. The minimum TXx value at Sf.



Gheorghe-Delta station was 19.46°C in 1978 and at Gura Portiței station 19.68°C in 1987. The highest annual average TXx was recorded at Constanța station with a value of 22.71°C, the other stations recorded as follow: Mangalia 22.69°C, Gura Portiței 21.5°C, Sf. Gheorghe-Delta 21.31°C. The evolution of TXx is represented in Fig.8, which shows that Mangalia and Constanța stations had similar evolutions, with very

Fig. 8. Annual average TXx in the period 1961-2020 at meteorological stations used in study

close values, while the minimum values of the analyzed stations were recorded at Sulina station. In the analysed data set, uniform warming of TXx is observed in the last two years of analysis, 2019 and 2020 at all analysed meteorological stations in the Black Sea littoral area, with TXx exceeding 22-23°C, with the highest values at the Constanța meteorological station in both years of analysis. Regarding the average monthly TXx minimums, the minimum value was recorded by the Gura Portiței weather station in December, being 4.50°C, the average of the other TXx minimums being Sulina 5.30°C in December, Sf. Gheorghe-Delta 6.20°C in January, Constanța 4.90°C in January and Mangalia 6.90°C in January.

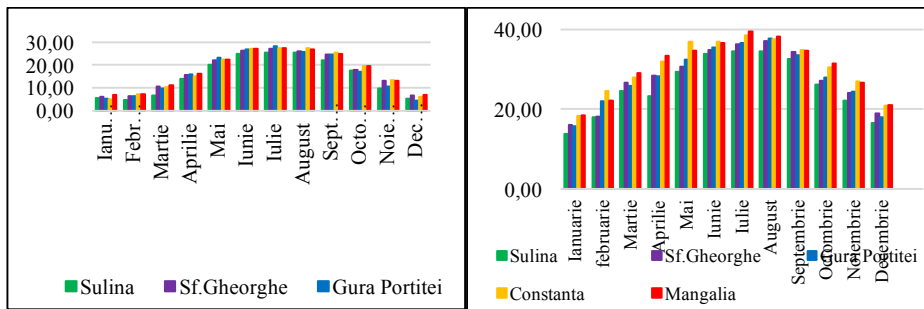


Fig. 9. Average monthly highs (left) and monthly lows (right) TXn in the period 1961 - 2020 at the meteorological stations used in study

Also concerning the monthly TXx minimums, the maximum value was recorded by the Gura Portiței station with a value of 28,20°C in July, followed by Constanța with 27.50°C in August, Mangalia with 27.40°C in July, Sf. Gheorghe-Delta 27°C in July and Sulina with 25.50°C also in July. Concerning the average monthly TXx maximums, it can be observed that the maximum value recorded was 39.50°C at Mangalia station, in July, followed by 38.50°C at Constanța, also in July, 37.70°C at Gura Portiței in August, 37°C at Sf. Gheorghe-Delta also in August and 34.50°C at Sulina in July. The evolution of the average monthly minimum and maximum TXx were highlighted in Fig. 9. Regarding the seasonal analysis of monthly mean TXx values at the meteorological stations analysed (Fig.10), the largest oscillations occur in the winter season, but significant variations are also observed in autumn and spring. In summer, the smallest variations of the average TXx maxima are observed at all the 5 analyzed stations.

The study also aimed at analysing the trends observed in the evolution of extreme maximum temperatures (3 indicators TXm, TXn and TXx), using the non-parametric Mann-Kendall test and the Sen estimator of the slope of the trends (expressed in °C/period), for a statistical significance threshold of at least 95% (p value < 0.05). The trend analyses at monthly, seasonal and annual levels observed over the period 1961-2020, using the Mann-Kendall test are summarised in Tables 1, 2 and 3.

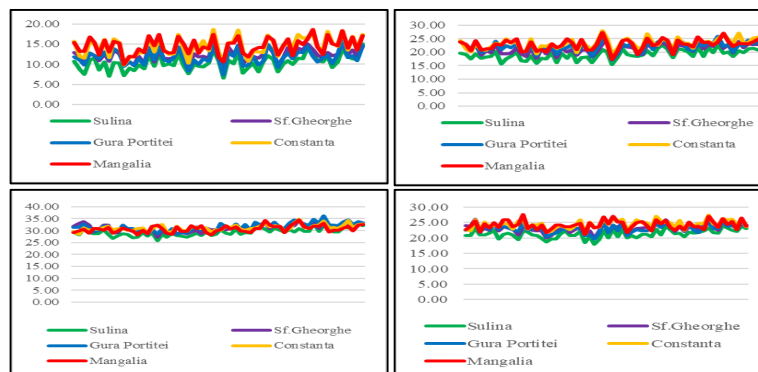


Fig. 10. Seasonal evolution of TXx in the period 1961 - 2020 at the meteorological stations used in study: winter, spring (up), summer and autumn(down)

The main conclusions of these analyses are:

1. Regarding the analysis of the TXm trend, at monthly level, the trend is an increasing one at all the 5 meteorological stations analysed (Tab.1), with a maximum monthly rate in March at the Constanța station with 4.3°C (very high warming rate), followed by the warming in August also at the Constanța station with a value of 3.78°C. The highest temperature increases occur in March and August, with an increase rate above 3°C, with a lower warming trend recorded at Gura Portiței station.

The significant warming trend is also observed in June and July (summer), with a rate exceeding 2°C at most of the stations analyzed, but also in February and January (winter), with the highest warming rates recorded at Constanța station. At the seasonal level, the evolution of TXm averages shows a marked warming with maximum rates of 3.44°C at Constanța station in the summer season and over 2°C at all other stations analyzed, namely 2.91°C at Sulina, 2.59°C at Mangalia and 2.29°C at Gura Portiței. Significant warming is also observed in winter, with more than 2°C at Constanța and Sf. Gheorghe-Delta stations, but also in spring at all stations analyzed, except at Gura Portiței.

Table 1. Observed trends (°C/period) in the evolution of mean maximum air temperatures at weather stations on the Romanian Black Sea coast (1961-2020)

Time scale	Weather station				
	Sulina	Gura Portiței	Sf. Gheorghe	Constanța	Mangalia
Jan	1.62	1.08	2.02	2.09	1.54
Feb	2.28	1.06	2.79	3.31	2.7
Mar	3.16	1.63	3.32	4.30	3.22
Apr	1.25	0.34	1.80	2.02	1.37
May	1.76	0.67	1.97	2.93	2.07
June	2.30	1.71	2.43	2.78	2.07
July	3.01	2.09	2.62	3.49	2.59
Aug	3.10	2.80	3.19	3.78	2.77
Sept	1.64	2.05	1.45	2.26	1.77
Oct	0.82	1.93	0.98	1.3	0.61
Nov	-0.16	0.39	-0.32	0	-0.79
Dec	1.55	0.42	1.87	1.77	1.47
Winter	1.66	0.96	2.12	2.13	1.57
Sprin	2.17	0.96	2.39	3.16	2.19
Summer	2.91	2.29	2.99	3.44	2.59
Autumn	0.73	1.69	0.73	1.22	0.43
Annual	1.86	1.45	2.01	2.50	1.8

In spring, a maximum warming is observed in March at Constanța station, with a significant warming of 3.16°C. In autumn, the lowest warming of TXm is observed. Annually, the observed rate increases are between 1.45°C at Gura Portiței station and 2.50°C at Constanța station. Significant increases are recorded at all the meteorological stations analysed, with an average of 1.92°C. The smallest increases are recorded at Gura Portiței station, but statistically significant here too, with 1.45°C.

2. As regards the analysis of the TXn trend, at monthly level, the trend is an increasing one at the level of all the 5 meteorological stations analysed (Tab.2) with a monthly maximum in August of 5.04°C at Gura Portiței station.

Significant warming is also observed at Gura Portiței station in July and July, with over 4°C, but also in March with 3.68°C. Significant warming of TXn is also recorded at Constanța station in August, with a maximum of 4.77°C, in June and July with more than 2°C, but also in March with more than 3°C (3.66°C).

Table 2. Observed trends (°C / period) in the evolution of minimum maximum air temperatures at weather stations on the Romanian Black Sea coast (1961-2020)

Time scale	Weather station				
	Sulina	Gura Portiței	Sf. Gheorghe	Constanța	Mangalia
Jan	1.32	0.22	0.88	0.62	0.95
Feb	0.93	0.32	0.88	0.95	0.18
Mar	2.90	3.68	3.33	3.66	3.50
Apr	0.18	0.60	1.34	0.80	0.43
May	1.54	1.16	1.50	2.05	1.85
June	1.33	4.11	2.62	2.88	2.62
July	3.14	4.41	3.22	2.82	2.43
Aug	3.03	5.04	4.28	4.77	3.91
Sept	0.91	2.61	2.34	2.11	0.74
Oct	0.00	0.00	0.14	0.28	-0.51
Nov	0.63	1.46	0.81	1.41	0.30
Dec	0.86	1.13	1.59	0.84	0.96
Winter	0.96	0.50	1.00	0.67	0.86
Spring	2.00	2.06	2.59	2.25	2.12
Summer	2.80	4.67	4.00	3.80	3.11
Autumn	0.20	1.15	0.91	1.08	0.14
Annual	1.35	1.91	1.92	1.80	1.20

At seasonal level, the highest increases are in summer, with values of more than 4°C at Gura Portiței and Sf. Gheorghe-Delta stations, more than 3°C at Constanța and Mangalia and more than 2°C at Sulina station. The seasonal warming maximum is therefore in summer, with 4.67°C at Gura Portiței. Significant warming values are also observed in the spring season, with values above 2°C recorded at all 5 stations analysed. In autumn and winter, the warming of TXn is less significant, with values around 1°C. At annual level, the highest values of TXn are recorded at the stations Sf. Gheorghe-Delta and Gura Portiței, with differences of only 0.01°C between them, namely 1.92°C and 1.91°C respectively. At all stations, the annual heating rate

exceeds 1°C, being 1.80°C at Constanța, 1.35°C at Sulina and 1.20°C at Mangalia. The average annual rate at all stations is 1.64°C.

3. As regards the analysis of the TXx trend, at monthly level, the trend is increasing at all the 5 meteorological stations analysed (Tab. 3), with a monthly maximum of the increase rate in February of 5.00°C at Constanța station. Significant warming of more than 4°C is also recorded in February at Mangalia and Sulina stations. Significant warming of 4.36°C is recorded at Sulina station in March and over 2°C at Sf. Gheorghe-Delta and Constanța stations.

Table 3. Observed trends (°C/period) in the evolution of maximum air temperatures at weather stations on the Romanian Black Sea coast (1961-2020)

Time scale	Weather station				
	Sulina	Gura Portiței	Sf. Gheorghe	Constanța	Mangalia
Jan	2.50	0.85	1.50	3.26	2.00
Feb	4.00	1.25	3.60	5.00	4.24
Mar	4.36	1.57	2.97	2.51	0.65
Apr	1.32	-0.50	0.87	1.10	0.32
May	3.43	3.87	2.71	4.80	3.50
June	3.11	3.54	1.88	1.52	1.71
July	3.88	3.75	2.34	3.52	2.28
Aug	3.70	4.26	3.00	1.89	1.84
Sept	2.93	1.66	1.52	2.69	1.55
Oct	2.00	1.80	2.14	1.71	1.17
Nov	0.58	-0.51	0.37	0.51	-1.55
Dec	1.80	0.63	1.33	0.38	0.00
Winter	2.71	0.91	1.92	2.57	1.65
Spring	3.10	1.67	2.61	2.85	1.56
Summer	3.40	3.83	2.55	2.07	1.78
Autumn	1.83	1.06	1.04	1.86	0.72
Annual	2.64	1.83	1.97	2.38	1.58

At seasonal level, the highest value of TXx is recorded by Gura Portiței station, in the summer season, with an increase rate of 3.83°C, followed by Sulina with 3.40°C. Also at Gura Portiței a significant increase is observed in spring, with 3.10°C, but also in winter with 2.71°C. Large increases are also observed in winter at Sulina, with 2.71°C. The smallest seasonal increases are in autumn, but here too there are statistically significant increases of more than 1°C at all stations analysed. At annual level, the highest growth rate is at Sulina station, with a value of 2.64°C, followed by Constanța, with 2.38°C. At all other stations, at annual level, the increase is significant, with more than 1.50°C. The annual average growth rate at all stations analyzed is 2.08°C. Comparing the average annual growth rates of TXm,

TXn and TXx, it can be observed that at all the analyzed stations we have significant increases over the analyzed period with a minimum of 1°C and a maximum exceeding 2°C. The highest increases for TXm and TXn indicators are observed at Gura Portiței station, while TXx is observed at Sulina and Constanța. If at Sulina the maximum temperatures had comparably lower temperatures than the other stations, it is observed that due to the tendency of faster increase than at the other stations, it will approach the evolution curve of the other stations (possibly exceeding them in the future).

At Constanța station the highest increases are observed in the spring season, analysing the trend of all three indicators TXm, TXn and TXx. The highest growth trends in the summer season are observed for all indicators at Sulina station, while the highest increases in winter are observed at Constanța station. In autumn there are no large variations in the growth rate of TXm, TXn and TXx indices. Also notable are the TXx increases in the winter months of January and February, with values ranging from 0.85°C (minimum at Gura Portiței) to 5°C at Constanța.

5. CONCLUSIONS

The study revealed an ongoing and intense warming process along the entire Black Sea coast of Romania. The observed increasing trends in maximum temperature are significant in all seasons, particularly strong in summer and more diminished in autumn. The highest increases are observed in the northern coastal areas at Gura Portiței and Sulina stations. In the south, at Constanța and Mangalia stations, the increase is also significant and steady.

The observed trends are particularly relevant for the adaptation mission, especially for highly sensitive sectors such as the public health, tourism and biodiversity, in relation to the observed and expected effects thermal stress, urging the need to adaptation planning to minimize its adverse effects. The observed warming and associated heat stress are expected to act jointly with those of the local pollution, amplifying the negative impact on population health, power infrastructure, water resources and the transport sector (i.e. the state of asphalt). In cities, the heat stress associated with heat waves is accentuated by the urban heat island effect, the intensity of which depends on a number of characteristics such as city morphology, increased emissions, population density and changes in land cover and land use (Cheval et al., 2022). The changes observed in the monthly, seasonal and annual evolution of the maximum temperature affect all regions of Romania, both in terms of quality of life, instability of economic and social services, and in terms of sectoral activities (agriculture, forestry, fisheries, industry, energy, transport, construction, tourism, etc.).

REFERENCES

1. Busuioc Aristița, Dobrinescu A., Bîrsan M.V., Dumitrescu A., Orzan Alina (2014), *Spatial and temporal variability of climate extremes in Romania and associated large-scale mechanisms*, Int. J. Climatol. DOI : <https://doi.org/10.1002/joc.4054>.

2. Bojariu Roxana, Chițu Zenaida, Dascălu S.I., Gothard M., Velea Liliana, Burcea R., Dumitrescu A., Apostol L., Amihăesei V., Marin Lenuța, Crăciunescu V.S., Irimescu A., Mătreacă M., Niță A., Bîrsan M.V. (2021): *Climate change - from physical basis to impact and adaptation*, 222 p. revised and added edition, Printech Publishing House, Bucharest, Romania.
3. Cheval S., Bulai Anca, Croitoru Adina-Eliza, Dorondel Ș., Micu Dana-Magdalena, Mihăilă D., Sfică L., Tișcovschi A. (2022a). *Climate change perception in Romania*. Theoretical and Applied Climatology. DOI: <https://doi.org/10.1007/s00704-022-04041-4>.
4. Bîrsan M.V. et al.(2018), *Spatio-temporal changes in annual temperature extremes over Romania (1961–2013)*, Pag.no. 816, p.11.
5. Raliță I. (2005), *Criterii de reprezentativitate a platformelor stațiilor meteorologice pentru evaluarea schimbărilor climatice*, ANM, p. 151-185, București.
6. The European Climate Adaptation Platform Climate-ADAPT Home — Climate-ADAPT (europa.eu), accessed on 11.11.2022.
7. IPCC Intergovernmental Panel on Climate Changes ,IPCC (2007), *Impacts, Adaptation and Vulnerability – Summary for Policymakers*.<https://www.ipcc.ch/>, accessed on 05.11.2022.
8. IMF Climate Change Indicators Dashboard : <https://climatedata.imf.org/>, accessed on 12.11.2022.
9. RO-ADAPT National Strategy on Adaptation to Climate Change for the period 2022-2030 with a view to 2050, SIPOCA 610 Code MySMIS2014+.