Spatial distribution of air temperature and atmospheric precipitations in the NE Region - Romania

Distribution spatiale de la température de l'air et des précipitations atmosphériques dans la Région du NE de la Roumanie

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ABSTRACT: The study analyzes the main climatic elements in the NE Romania Region, during the period (1961-2024). The studied area has a transitional climate, deeply influenced by the advections of oceanic, Eastern European, and Scandinavian-Baltic air masses. The relief, with its stepped distribution, plays an important role in the layered distribution of the values of the climatic elements analyzed. On the peaks and saddles of the Eastern Carpathians, the average air temperatures range from 1°C at Ceahlău Toaca to 4.9°C at the Poiana Stampei station, at the plateau stations from 7.8°C at Rădăuți to 10.3°C at Bârlad, and at the plain stations between 9.6°C at Botoșani and 10.1°C at the Iași station. Precipitation increases with altitude, but there are notable exceptions - Ceahlău Toaca (700.5 mm), where active air dynamics affect measurements. The results show a layered distribution of the two elements analyzed, influenced by relief and atmospheric dynamics.

KEY WORDS: NE Region, air temperature, atmospheric precipitation.

RÉSUMÉ: Cette étude analyse les principaux éléments climatiques du nord-est de la Roumanie sur la période 1961-2024. La zone étudiée présente un climat de transition, fortement influencé par l'advection de masses d'air océaniques, d'Europe de l'Est et scandinaves-baltes. Le relief, avec sa distribution en gradins, joue un rôle important dans la répartition stratifiée des valeurs des éléments climatiques analysés. Sur les sommets et les cols des Carpates orientales, les températures moyennes de l'air varient de 1°C à Ceahlău Toaca à 4,9°C à la station de Poiana Stampei; sur les plateaux, de 7,8°C à Rădăuți à 10,3°C à Bârlad; et en plaine, de 9,6°C à Botoșani à 10,1°C à Iași. Les précipitations augmentent avec l'altitude, mais il existe des exceptions notables, comme Ceahlău Toaca (700,5 mm), où une dynamique atmosphérique active affecte les mesures. Les résultats montrent une distribution stratifiée des deux éléments analysés, influencée par le relief et la dynamique atmosphérique.

MOTS-CLÉS: Région Nord-Est, température de l'air, précipitations atmosphériques.

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1. Introduction

The regime and distribution of the thermo-pluviometric complex is a subject of great climatic importance, forming the basis of many regional climate studies (Apostol, 2000; Apostol, 2004; Mihăilă, 2006; Nistor, 2014; Sfîcă, 2015). The analysis of large-scale climate change (Climate Change 2021) in Romania or certain regions of it (Croitoru and Piticar, 2012; Piticar and Ristoiu, 2014; Mihăilă et al., 2021) has also required prior research into the territorial distribution of air temperature and precipitation. The spatial distribution and temporal variability of these elements are greatly influenced by physical-geographical and dynamic factors.

In our country, specialized studies emphasize the differentiated nature of thermo-pluviometry as a result of the dynamics, distribution, and structure of the relief (Bâzâc, 1983). The orographic barrier formed by the Carpathian arc conditions the contrasts between the colder and wetter intramountainous areas and the warmer and less rainy extracarpatic areas. This aspect has also been detailed in studies addressing climate risks (Bogdan and Niculescu, 1999), climate variability (Busuioc, Bîrsan, and Bojariu, 2010), and the trend of increasing average annual temperatures (Administrația Națională de Meteorologie [ANM], 2024; Bojariu R. et al., 2021), and decreasing precipitation in the summer in the eastern part of the country.

The thermo-pluviometric regime is influenced by regional atmospheric circulation. The North-East Region of Romania (RNER) is located at the intersection of Atlantic, continental, and maritime climatic influences generated by the Black Sea. Regional and local atmospheric circulation, including the effect of regional and local winds such as the crivăț and foehn, together with temperature inversions determined by the configuration of the relief, further contribute to the complexity of the spatial distribution of climatic parameters in this region, generating local climatic peculiarities (Apopei, Mihăilă, and Bistricean, 2020; Sfîcă, 2013).

The RNER is climatically distinct, presenting a contrast between the inner frame of the Eastern Carpathians and their eastern frame, respectively the neighboring extra-Carpathian units. The frequent thermal anomalies in this region reflect both the influence of atmospheric circulation and altitudinal stratification (Mihăilă, 2006; Sfîcă, 2013). Recent studies confirm that air temperature in this area is dependent on altitude, with temperature differences between the mountains and the plains reaching 10–12°C (Piticar, 2013). In the Moldavian Plain, average annual temperatures range between 8 and 9°C, increasing towards the south and decreasing towards the north (Mihăilă, 2006). In more restricted areas, at the local level, there are urban and peri-urban microclimates, generated by the morphology of the terrain and anthropogenic factors, such as the situation in Iași (Alexe and Apostol, 2017). In these areas, the air temperature is higher than in the surrounding areas (Mihăilă et al., 2024; Sfîcă et al., 2023).

In the RNER, precipitation decreases quantitatively from west to east, with the decrease in altitude of the relief, but also under the influence of the foehn effect (Apostol, Pîrvulescu, 1987). In the Carpathians, the high amount of precipitation is determined both by Atlantic influences and by the condensation of moist air masses, compared to the extra-Carpathian areas where precipitation is moderate. In the Moldavian Subcarpathians, rainfall decreases, with annual values frequently exceeding 700 mm (Apostol, 2004), while in the Central Moldavian Plateau, annual averages are around 550–600 mm, with areas below 500 mm (Larion, 2004; Patriche, 2005). For the eastern part of the region, recent studies indicate precipitation values close to 500 mm, confirming the semi-arid nature of some sectors (Corduneanu et al., 2021). The region is frequently affected by droughts (Mihăilă and Tănasă, 2005).

In this context, a territorial analysis of rainfall is necessary to understand the reflection of geographical and dynamic factors at regional and local scale. Due to its location between the East European Platform and the Eastern Carpathians and its exposure to multiple external climatic influences, the RNER is a relevant territory from this research perspective (Stoenescu and Țâștea, 1964; Mihăilă, 2004). The increase in temperature associated with a slight deficit in precipitation, recorded after 1991 in the summer season (ANM, 2024), favors the conditions for the formation of drought in the RNRE.This paper analyzes the spatial distribution of the main climatic elements—air temperature and precipitation—in the RNER, with the aim of highlighting the territorial differences of these elements in relation to climatogenic factors. To achieve this goal, the scientific approach aims to achieve the following objectives:

- **O1** processing and interpreting climate data from 1961 to 2024, obtained from meteorological stations in the region;
- **O2** highlighting the areas with the highest and lowest temperatures and delimiting the territories with excessive rainfall, close to the regional average, or deficient rainfall;
- **O3** correlating temperature and rainfall values with physical and geographical factors (altitude, exposure, atmospheric circulation) to explain territorial differences.

2. Study area

Located between 48° 15’N - 46° 00’N north latitude and 28° 15'E - 24° 56'E east longitude, RNER borders Ukraine to the north, the Republic of Moldova to the east, the counties of Galați and Vrancea to the south, and the counties of Covasna, Harghita, Mureș, Bistrița Năsăud, and Maramureș to the west. From an administrative point of view, it covers the territory of six counties: Suceava, Botoșani, Neamț, Iași, Bacău, and Vaslui.

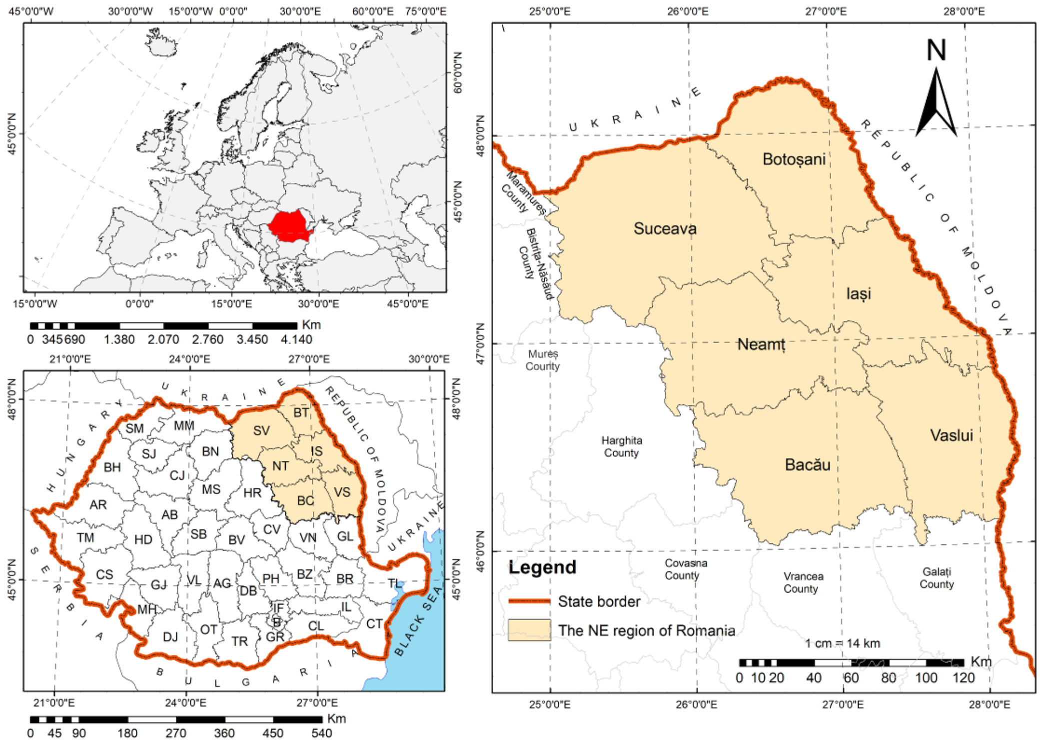


Figure 1 Geographical location of the RNER.

Within the RNER, the relief is varied, characterized by a succession of steps that gradually descend from west to east. In the west, the region overlaps the central and eastern part of the Eastern Carpathians, where the Ceahlău meteorological stations are located at an altitude of 1897 m and Poiana Stampei at 923 m. In the east of the mountain range, in the Subcarpathian step, recordings were made at the meteorological stations in Piatra Neamț, Târgu Neamț, and Târgu Ocna, and to the east and north of the Subcarpathians, in the plateau and hilly plain, where most of the weather stations are located (Rădăuți, Suceava, Roman, Cotnari, Bacău, Darabani, Botoșani, Iași, Vaslui, Bârlad).

This spatial distribution of the meteorological network allows for the capture of climatic differences generated by the relief levels, from the mountain peaks to the hilly plains in the east of the region. Of the six counties that make up the RNER, Suceava, Neamț, and Bacău are mainly located in the mountainous, sub-Carpathian, and plateau areas, while Botoșani, Iași, and Vaslui mainly overlap the plateau and hilly plain areas.

Approximately 60% of the region's surface area is occupied by plateau and plain, and the Moldavian Plateau extends across all counties in the region. The eastern part is characterized by low altitudes, typical of the Moldavian Plain. The depressions (Dornelor, Rădăuți) and valley corridors in the region (Moldova, Siret) generate thermal inversions due to the topographical configuration, a phenomenon that can determine local microclimates.

3. Methods

The database used includes the results of meteorological measurements taken at 17 stations (Table 1), distributed relatively evenly across the area of interest. The Iezer meteorological station was used as a support station for a more relevant interpolation of meteorological data, as it is located nearby, in the mountainous area, in the north-west of the RNER.

Table 1 Geographic coordinates of meteorological stations in the RNER

No.	Weather station*	Altitude	Latitude N	Longitude E
1.	Bacău	184	46°33'12	26°54'51
2.	Bârlad	172	46°13'57	27°38'37"
3.	Botoșani	161	47°44'08	26°38'43"
4.	Ceahlău Toaca	1897	46°58'39	25°56'59"
5.	Cotnari	289	47°21'29	26°55'32"
6.	Darabani	258	48°11'42	26°34'22"
7.	Iași	100	47°09'48"	27°37'42"
8.	Iezer	1785	47°36'05	24°39'10"
9.	Piatra Neamț	314	46°56'03"	26°23'20"
10.	Poiana Stampei	923	47°19'28	25°08'03"
11.	Rădăuți	389	47°50'15	25°53'25"
12.	Roman	216	46°58'09"	26°54'39"
13.	Suceava	352	47°37'56	26°14'27
14.	Ștefănești-Stânca	108	47°49'56	27°13'11"
15.	Târgu Neamț	384	47°12'43	26°22'45"
16.	Tg. Ocna	241	46°16'22	26°38'32"
17.	Vaslui	116	46°38'44	27°42'51"

*the weather stations are ordered alphabetically

The data used resulted from measurements taken at these stations over a period of 63 years (1961-2024) and come from the National Meteorological Administration Archive and the data.gov.ro platforms (n.d.). *Climatological data sets,* ROCADA - Bîrsan și Dumitrescu (2014), Meteomanz, and ECAD. Statistical processing of the data series was performed using Excel. The thermal parameters calculated were: annual, winter, summer, January, and July average temperatures. At the same time, the minimum and maximum air temperature values were extracted from each station.

The rainfall parameters calculated for each station included the annual averages, winter averages, summer averages, and the averages for January-February and May-June, respectively.

The spatial representation of the climate indices was performed using ArcGis 10.8 software, using the *Spatial Analyst Tools* (Map Algebra, Raster Calculator) functions. The interpolation of climate values was performed using the Regression–Kriging method, in which the observed values were modelled according to altitude, and the residuals were subsequently interpolated using ordinary Kriging. This combination ensures a reduction in errors and a more accurate representation of spatial variation. Subsequently, thermal and pluviometric profiles were created using the 3D Analyst function, and the resulting data were transferred to Excel for analysis in correlation with altitude values.

4. Results and discussion

The novelty of the study lies in the long-term integration (1961–2024) of data from 17 meteorological stations, which allows for the clear delimitation of areas with excess rainfall, close to the regional average, or deficient rainfall, as well as major thermal contrasts. The analysis shows that the RNER is a heterogeneous climatic space, where the interaction between zonal factors (atmospheric circulation) and local factors (altitude, exposure, landforms) generates marked territorial differences, with implications for water resources, agriculture, and the environment.

4.1. Mean annual temperature in the RNER

The average annual temperature in the RNER, which resulted from averaging the temperature data for the period 1961-2024, is 8.2°C. Figures 2a and 2b show the spatial distribution of temperature values in the RNER, correlated with altitude.

Following the interpolation of average annual temperature values with the digital elevation model, we observe that average temperatures gradually decrease from east to west with increasing altitude and also from south to north with increasing latitude. Latitude determines different exposure to solar radiation, thus influencing air heating, while altitude acts as a cooling factor, reducing the average temperature by about 0.6^{o} C for every 100 m of altitude. The average temperature gradient across the entire RNER according to average annual temperature values is (-0.7°C/100 m).

The highest average annual temperature was calculated for Bârlad (10.3°C), and the lowest (1°C) for the Ceahlău Toaca station. We observe differences in temperature values at different stations compared to the regional average. Temperatures below the regional average (between 1°C and 4.9°C) are specific to stations in the mountainous area and in the northwestern, depressional extremity of the Moldavian Plateau (7.9°C in Rădăuți). As the altitude decreases, starting with the sub-Carpathian hills and plateau, the calculated values exceed the regional temperature average, ranging from 8.3°C in Suceava, 9.8°C in Cotnari, and 10.3°C in Bârlad.

The thermal profile with direction A–B, drawn between the extreme NW and SE of the region (Figure 2a), highlights the thermal differences between stations (Figure 2b), differences imposed by latitude, altitude (Figure 2b), the overall morphology of the region, the particularities of the active surface, or the Baltic climatic influences from outside the region and the continental influences from the east of the region.

Across the country, during the period 1958–2023, the increase in the average annual temperature exceeded the European average (+1.99°C), by approximately +0.12°C. Among the regions most affected by this trend were the northern areas of the country (ANM, 2024). The increase in the average annual temperature contributes to the drought phenomenon.

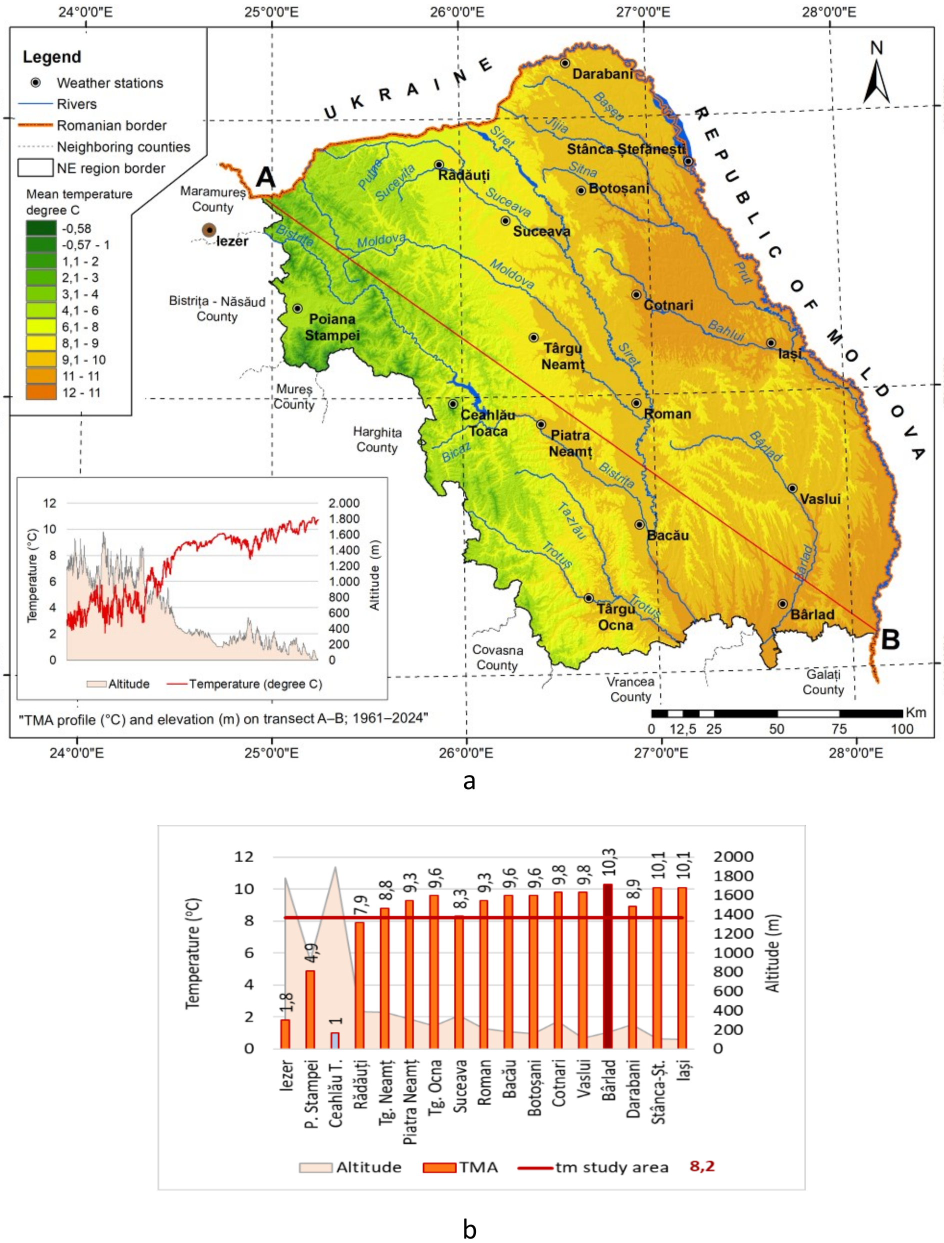


Figure 2a, b Spatial distribution of mean annual temperature values in the RNER (1961 - 2024).

The results are consistent with the general characteristics described by Mihăilă (2004), Croitoru and Piticar (2013), who showed that spatial temperature differences in Moldova are conditioned both by morphometric factors and by the geographical position at the intersection of continental influences from the east and Baltic influences from the north. In contrast, in the central hilly and plateau areas (Cotnari, Iași, Roman), the average annual temperatures exceeding the regional average reflect a combination of lower altitudes, southern exposure of the slopes, and the effect of continentality. The highest temperature (in Bârlad) can be associated with both the low altitude and the location in the southern part of the region, where sporadic Mediterranean influences can accentuate summer warming.

4.2. Mean winter and summer temperatures for the RNER

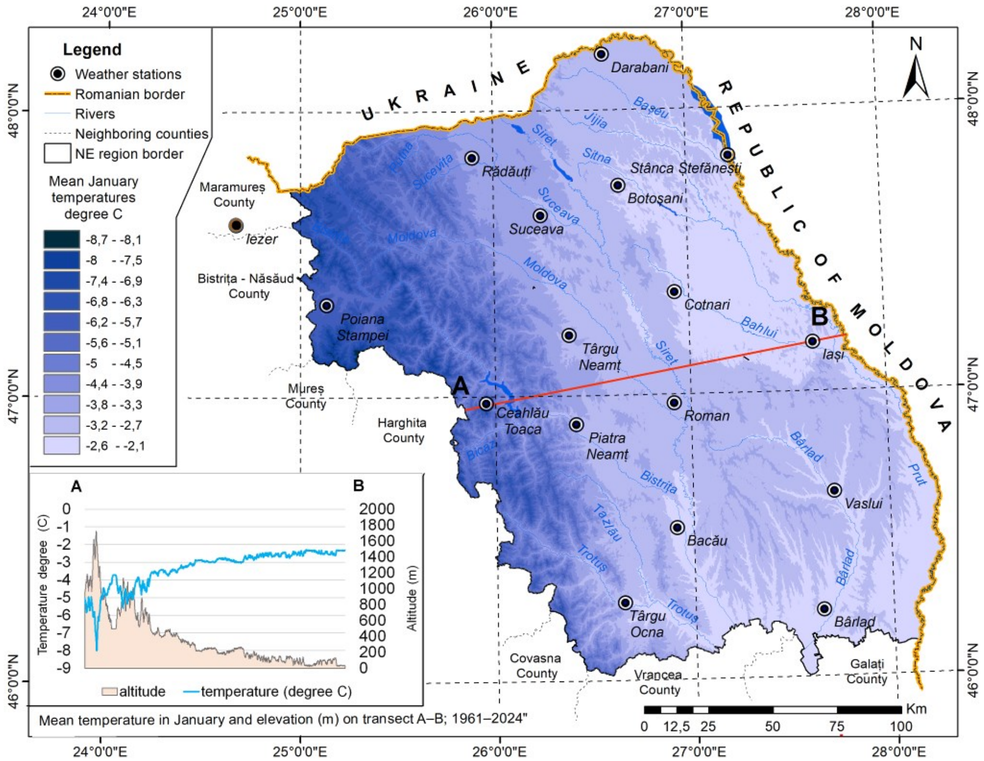
During winter (December-February), the average temperature is characterised by low values, reflecting the predominant influence of the continental dry climate, manifested by cold air advection from the east, thermal inversions and frequent intense frosts. In the RNER, winters are more severe than in the southern regions of the country, a phenomenon explained by the interference of Scandinavian-Baltic and continental climatic influences, but also by the effect of increased altitude in the sub-Carpathian and mountainous areas. The multi-year average temperature in winter is around -2.4°C, with notable territorial differences determined by the relief (local altitude) and other elements of the natural environment that define the structure of the topographical surface. Thus, in the mountainous area, the average winter temperature is -7.3°C at the Ceahlău-Toaca station, significantly lower than the regional average, while the maximum average winter temperature,-1°C, was calculated for the Bârlad meteorological station located in the Bârlad Plateau on the valley of the river of the same name and Târgu Ocna located in the Subcarpathians. The very low values in mountainous areas can be explained by the influence of altitude, and in intramountainous depressions by the frequency of thermal inversions, aspects also described by Mihăilă (2004) or Sfîcă et al. (2017).

During the summer months (June-August), the multi-year average temperature in the RNER is higher than during the rest of the year. This is mainly due to continental climatic influences, which cause heat waves and high temperatures, especially in the eastern part of the region, but also to altitude, which has a regional cooling effect, especially in the western parts. During the summer, anticyclonic baric fields and clear skies prevail on many days, favoring stability and consistently high temperatures. Thus, the average temperatures in June, July, and August range from 21.1°C in Bârlad to 9.5°C in Ceahlău Toaca, with the regional average for the summer season being 18°C, varying according to latitude, altitude, slope exposure, and other geographical features in the vicinity of weather stations (large cities, forests, watercourses, etc.).

4.3. Mean temperatures in January and July for the RNER

The average temperature for RNER in January, as calculated, is -3.6°C, reflecting the marked influence of the continental climate and the cold air masses that frequently penetrate from the north, northeast, and east. The lowest average temperatures for January were calculated for high altitudes. At the Ceahlău-Toaca station (1854 m), they drop to -8°C, highlighting the effect of altitude, orography, and very active atmospheric dynamics on air temperature (Figures 3a and 3b). In contrast, the higher value in January (-2.2°C) at the Târgu Ocna station can be explained by the low altitude (241 m), the southern position in the Moldavian Subcarpathians, and the sheltering effect of the relief, sometimes amplified by foehn episodes on the Oituz–Trotuș corridor (Apostol, 2004; Mihăilă, 2004). Similar foehn circulation phenomena have also been demonstrated for the Cotnari area, based on thermo-hydrometric arguments, by Apopei et al. (2024).

July is distinguished by average temperatures exceeding the threshold of 21°C at the Bacău, Darabani, Vaslui, Stânca-Ștefănești, and Iași weather stations, with a maximum value of 21.9°C calculated at Bârlad. This territorial temperature distribution is consistent with that of the annual temperature averages and highlights the occurrence of the highest temperatures in the eastern half of the region. These temperature characteristics are the result of the interaction between specific regional dynamic influences during the summer and the characteristics of the local relief.



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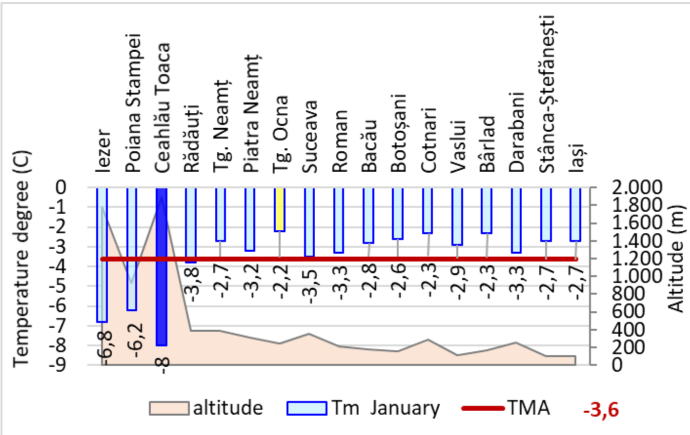

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Figure 3a, b Spatial distribution of January average annual temperature values in the RNER (1961–2024).

Examination of the thermal profile A – B between the NW and SE of the RNER for the month of July (Figure 4a) highlights notable temperature differences between the extremities of the region, with differences that can exceed 10°C (Figures 4a and 4b).

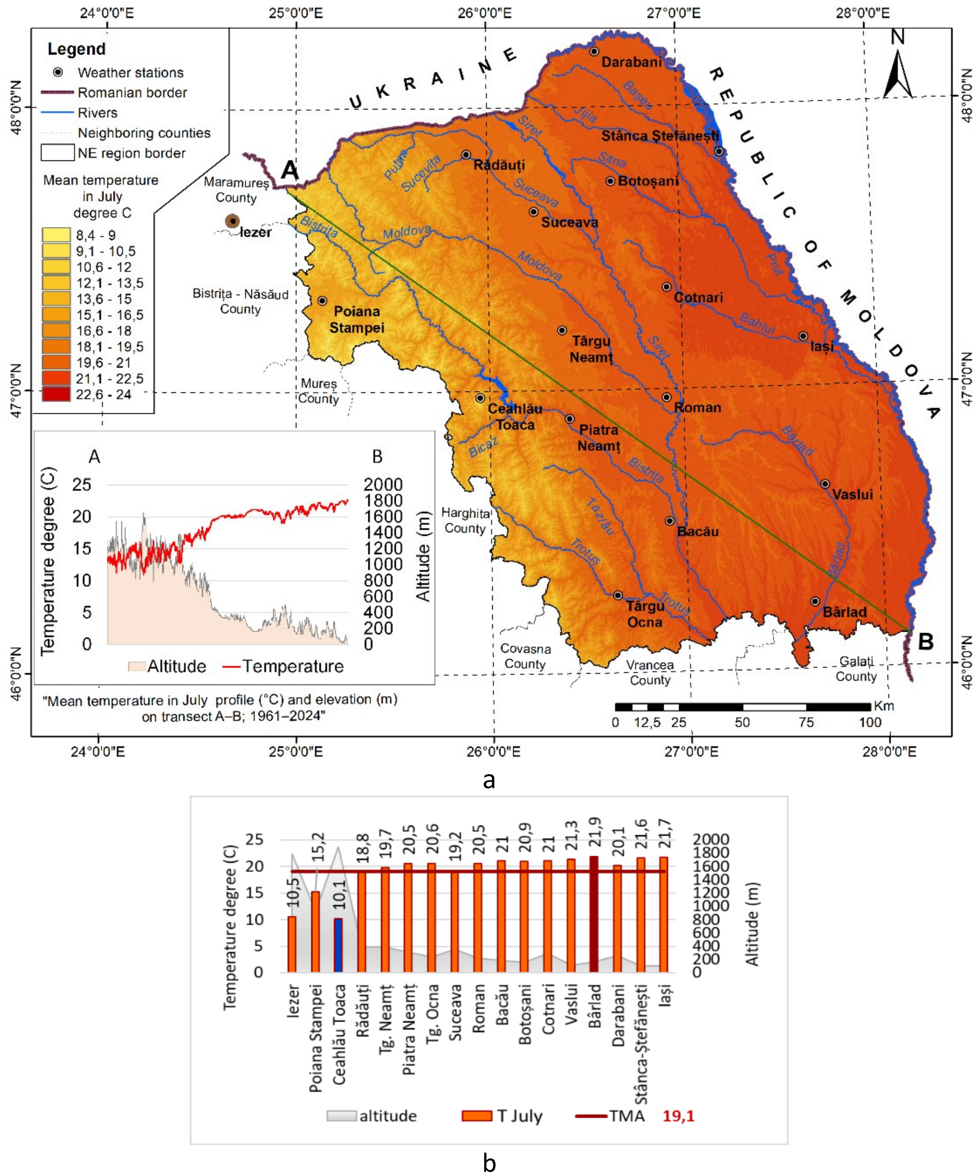


Figure 4a, b Spatial distribution of July average annual temperature values in the RNER (1961–2024).

These temperature differences are mainly explained by the influences of latitude and altitude, which distinctly shape the region's thermal regime.

4.4. Absolute minimum and maximum temperature for the RNER

The spatial distribution of minimum temperatures in the RNER is shown in Figures 5a and 5b. Thermal profile A–B, drawn in an east–west direction (Figure 5a), shows clear temperature differences, which correlate with variations in altitude between plains, hills, and mountains (Figure 5b). These differences highlight the major impact that relief has on the distribution of thermal values, especially during winter, outlining a complex and varied picture of the regional climate.

The location of the Rădăuți weather station in a low-lying area favors the accumulation of cold air, especially on clear, windless winter nights. Under such conditions, thermal inversion processes intensify: cold air, being denser, descends and settles over low-lying areas, such as depressions and valleys, leading to sharp drops in minimum temperatures.

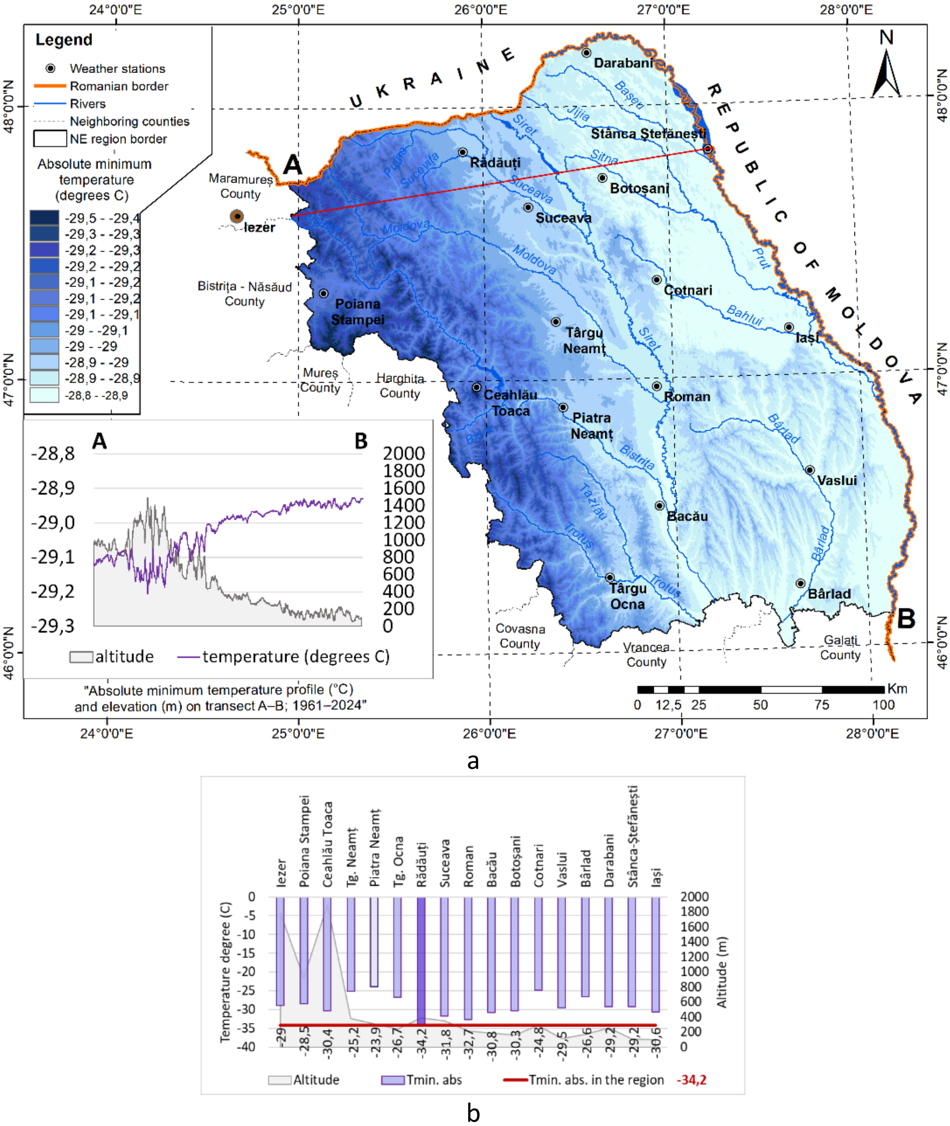
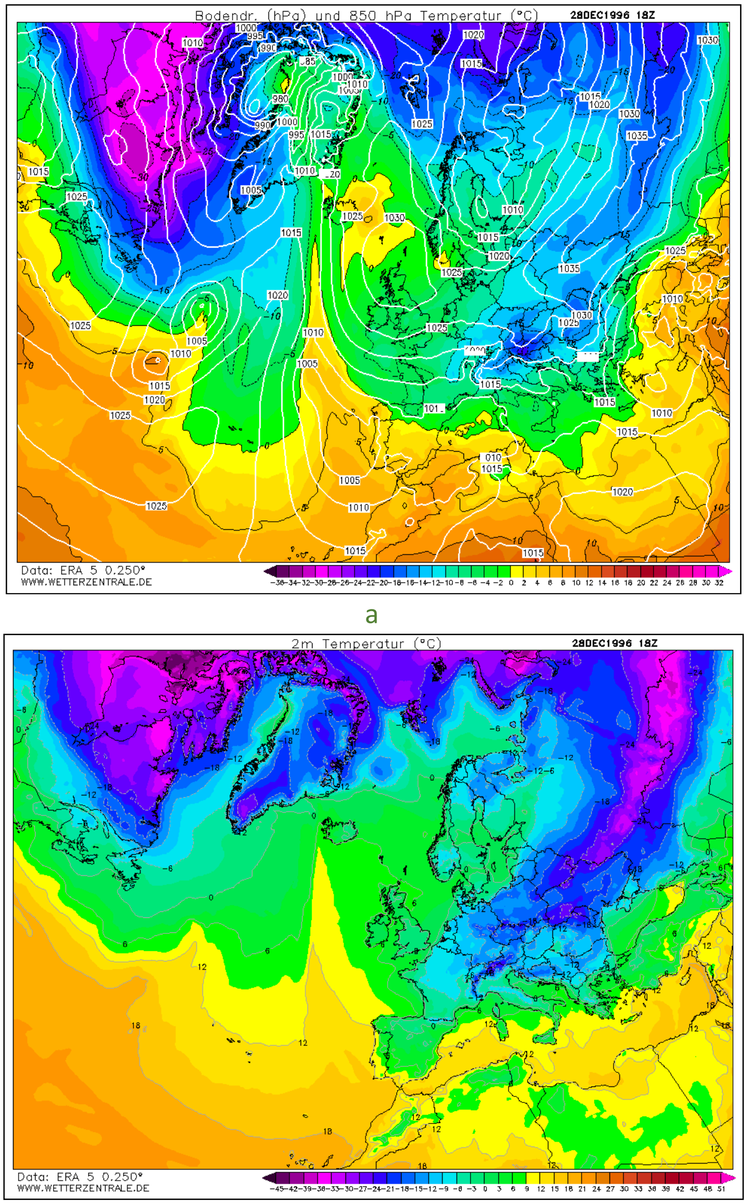


Figure 5a, b Spatial distribution of absolute minimum temperature values, in the RNER.

The absolute minimum temperature for the RNER was -34.2°C, recorded at the Rădăuți weather station on December 28, 1996. This temperature value was determined by the presence of thermal inversions specific to the cold season, associated with the penetration of very cold air masses (Figures 6a and 6b). The phenomenon of thermal inversions in Moldova, both at ground level and in the first 3000 m of the troposphere, was analyzed in detail by Apostol, Bărcăcianu, Ichim, and Sfîcă (2015). Days with such thermal characteristics are generated by the position and influence of baric centers as well as the associated air movements (Apostol, 2004; Busuioc et al., 2010;) which impose severe weather conditions in the region.



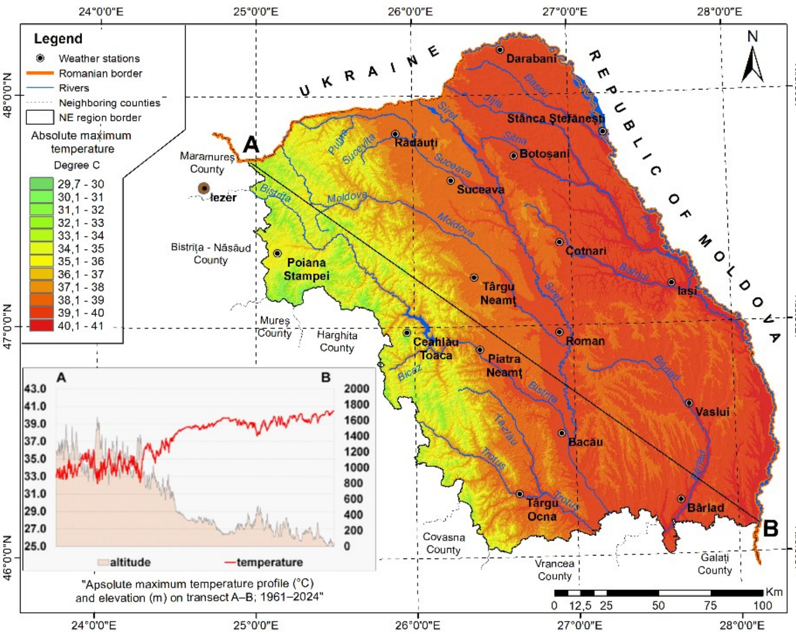
a

b

Figure 6 Configuration of the baric field above Europe at ground level, air temperature at the 850 hPa isobaric level (a), air temperature 2 meters above the active surface (b) on 28.12.1996, at 18^{00}. Source: www.wetterzentrale.de

The synoptic map (Figure 6a) shows a high-pressure field with values exceeding 1035 hPa, dominating central and eastern Europe and northwestern Russia. This continental anticyclone is moving predominantly from the northeast and east (Scandinavia, the Baltic Sea, and northwestern Russia) towards southeastern Europe, bringing cold polar air masses that have also affected Romania. In the northern part of the RNER, the cold air mass brought temperatures below -27°C (Figure 6b). The town of Rădăuți stood out as a veritable "cold pole" at the regional level, recording the lowest temperature in the period 1961-2024. On the same date, similar temperatures were recorded at the Suceava (-31.8°C)and Roman (-32.7°C) stations, both located in the valleys of the Suceava and Siret rivers, where temperature inversions occur frequently (Nistor, 2014; Apostol et al., 2015).

With regard to the absolute maximum temperatures recorded in the RNER territory, spatial analysis (based on Figures 7 a-c) shows that the highest values were recorded at the Stânca-Ștefănești weather station, where on August 7, 2012, temperatures rose to 41.3°C.



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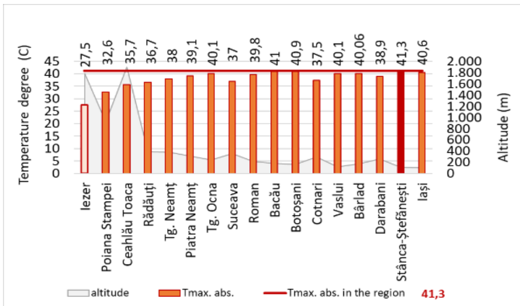

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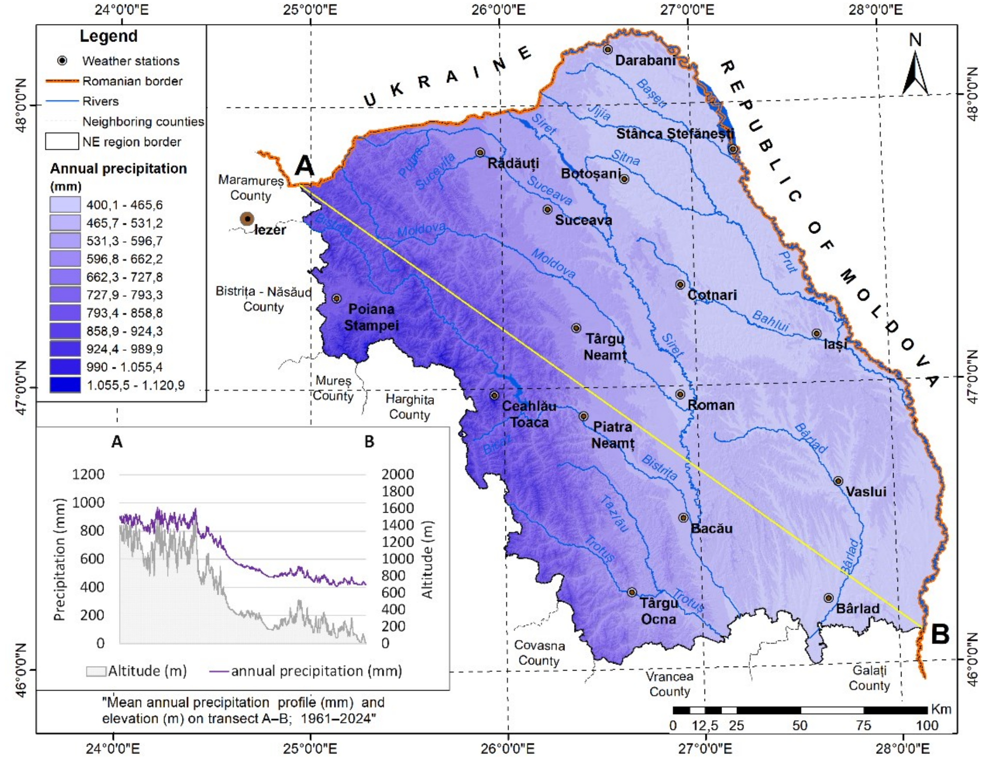
Figure 7a, b Spatial distribution of absolute maximum temperature values, in the North-East Region.

Along the northwest-southeast thermal profile (A-B), comparable maximum temperatures were recorded both along the Siret Corridor and in the subunits located east of it, in the Moldavian Plain, the Tutova Hills, and the Prut Valley. These areas are distinguished by absolute maximums that frequently exceed 39°C, according to the cartographic legend.

The spatial distribution of these temperature extremes is closely correlated with the particularities of atmospheric circulation, in particular with the periodic penetration of tropical air masses of South-West Asian or North African origin. These warm air advections cause significant increases in temperature, especially in low-lying areas, where the heating effect is amplified due to the low altitudes. Thus, the plains and low hills, especially those in the east and southeast of the region, become the most exposed to the extreme temperatures recorded during the summer, as confirmed by the study by Ichim, Apostol, Sfîcă, and Kadhim-Abid (2015), and these observations correlate with the results of Croitoru, and Piticar (2016) regarding the increased frequency of heat waves in eastern Romania, linked to persistent anticyclonic circulation and the continentality effect. The east-west temperature contrast, reflected in the differences between Bârlad and Ceahlău-Toaca, illustrates an average altitudinal gradient of approx. 0.6–0.7°C/100 m, a value close to that identified by Sfîcă et al., 2015.

5.1. Mean amounts of annual precipitation in the RNER

In this region, the average annual amount of precipitation is 621.9 mm. In the RNER, precipitation increases with altitude with an annual pluviometric gradient of 24.7 mm / 100 m.



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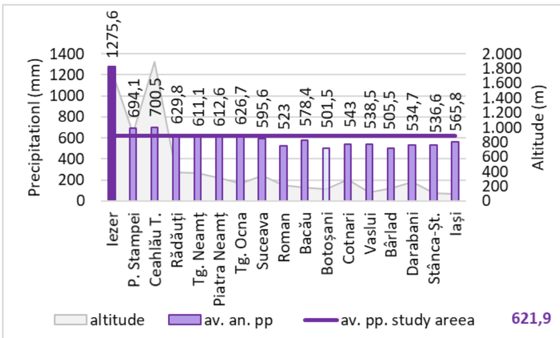

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Figure 8a, b Spatial distribution of annual precipitation in the RNER (1961 - 2024).

There are territorial differences that need to be detailed. Considerable differences can be observed at mountain stations: at Ceahlău-Toaca, the multi-annual average is 700.5 mm, while at Iezer it is 1274.6 mm. This discrepancy can be explained by local measurement conditions. At the Iezer weather station, located in a sheltered glacial cirque, the conditions for measuring precipitation are much more favorable than at Ceahlău Toaca, where the almost constant high winds prevent precipitation from reaching the rain gauge's receiving funnel.

This is more evident in the cold season with solid precipitation. The introduction of Vaisala rain gauges with wind-protected funnels, similar to Tretiakov rain gauges, improves the quality of rainfall observations at the two stations, especially at the Ceahlău Toaca station, where the average annual precipitation values have long been distorted by dynamic conditions that are unfavorable for measurements of the desired accuracy.

The mountain subunits of the Eastern Carpathians and the heights of the Moldavian Subcarpathians significantly influence the quantitative distribution of precipitation. Thus, altitude plays an essential role in increasing the amount of precipitation, which reaches values between 1000 and 1200 mm annually at high altitudes, while lower amounts of precipitation are recorded in the plains, between 505 and 565 mm.

We note a decrease in precipitation amounts from northwest to southeast, a climatic reality explained by the gradual decrease in altitude of the relief, but also by the influence of atmospheric circulation (Figure 8a, b). The moist air masses coming from the west, with a higher frequency, gradually lose their moisture content as they advance towards the east. The wide opening of the relief towards the east favors the penetration of continental air masses, characterized by a low moisture content (Tănasă, 2011).

The authors of the Report on the State of the Climate in Romania (ANM, 2024) in their analysis of the annual precipitation trend over the last 66 years mention that, at the national level, no significant variations were recorded, but a slight deficit was observed in the North-East Region. We will later observe their evolution both at the country and regional level.

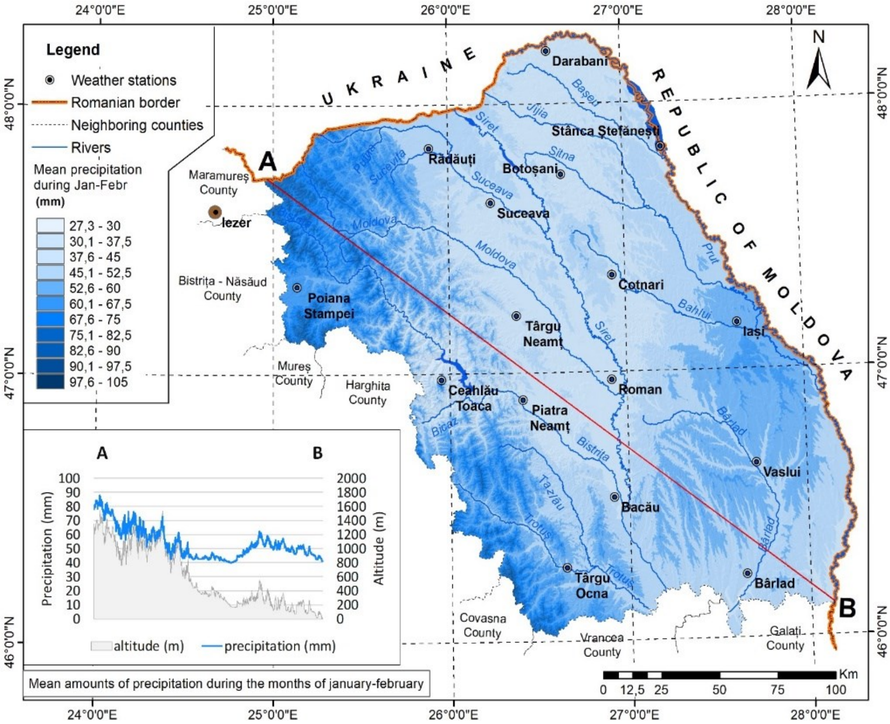
5.2. Average amounts of precipitation recorded in the winter and summer seasons in the RNER

Precipitation amounts in the RNER show pronounced seasonal variability due to oscillatory fluctuations in the general dynamics of the atmosphere and the interaction between solar radiation and the Earth's surface (Busuioc et al., 2010).

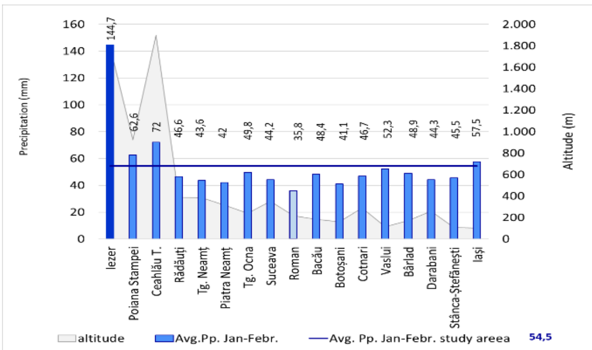
During winter, the average amount of precipitation in the RNER is 86.6 mm, with major spatial variations. The highest value (235.4 mm) is recorded at the Iezer station, while in Roman the average amount is only 59.8 mm. These contrasts reflect the direct influence of the relief: in the mountainous areas, precipitation is amplified by Atlantic influences and the orographic barrier effect, while in the lowlands sheltered by the circulation of humid air masses, the values remain low (Apostol, Pîrvulescu, 1987; Sfîcă, 2015). These results are consistent with the conclusions reached by Busuioc et al. (2015), according to which western circulation and associated synoptic factors play an essential role in the winter precipitation regime in the Carpathians. In the summer season, precipitation reaches a regional average of 251.9 mm. In the west of the region, along the Siret corridor and at mountain stations (e.g., Iezer), values frequently exceed the average, favored by altitude and the penetration of moist air masses from the west, which cause intensified rainfall (Apăvăloae et al., 1997). In the eastern part, the amounts are close to or below the average, highlighting the uneven nature of the summer distribution due to the diversity of the terrain and local topoclimatic influences (Mihăilă, 2006; Nistor, 2014; Tănasă, 2011). Overall, the seasonal distribution of precipitation in the RNER reflects the complex influence of local and regional factors.

5.3 Average rainfall value in the months of January-February and May-June

Based on the analysis of monthly precipitation amounts for the period 1961-2024, it was found that the lowest monthly averages are specific to January-February, and the highest to May-June. The average precipitation amount calculated for the entire region for January-February is 54.4 mm. This value outlines the period of the year with the lowest precipitation, predominantly in the form of snowfall, when low temperatures limit evaporation. The highest amount of precipitation in January-February was calculated for the Iezer station (143 mm). This value is about 50% lower than the average amount recorded at the same station during May-June. At the Roman weather station, the average amount for January-February is 35.8 mm, which is the lowest in the region. The map and rainfall profile A-B, oriented in the NW-SE direction (Figure 9a, b), confirm an important climatic reality: the amount of precipitation gradually decreases from the mountainous and sub-Carpathian areas in the west to the lower eastern territories, due to the decrease in altitude and the increase in the influence of the continental climate. Thus, the high regions (where the Iezer and Poiana Stampei weather stations are located) benefit from higher precipitation. In contrast, in the lower plains and plateaus (where the Iași, Bârlad, and Galați weather stations are located), the air is drier and the amount of precipitation is significantly lower. These spatial differences are accentuated in winter, when the moisture supply from the Atlantic and the Mediterranean Sea is reduced, and the Eastern European anticyclones bring cold and dry air, which inhibits the formation of precipitation. Therefore, the continental character is more pronounced, especially in the south-east of the region.



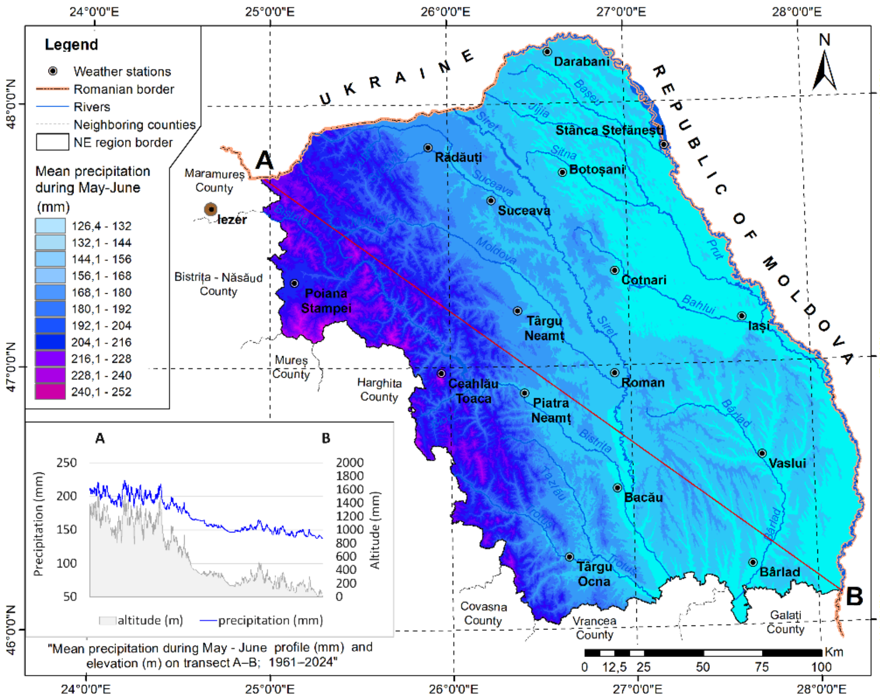
a



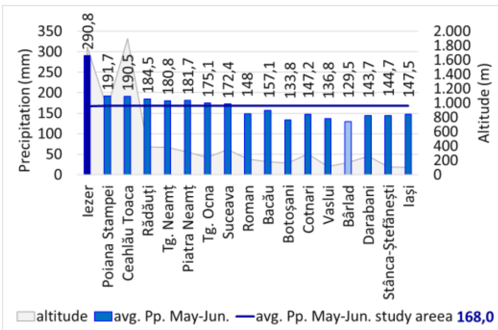
b

Figure 9 a,b Spatial distribution of precipitation during January - February in the RNER (1961 - 2024).

The highest amount of precipitation is recorded during an average year in May and June, as shown in Figure 10a, b. The overall average RNER for May-June is approximately 168 mm, but differences between stations can be significant. The highest amounts of precipitation in May-June fall at the Iezer weather station (291.4 mm), which is approximately 15% of the total annual precipitation reported for the entire region. This can be explained by the station's location in the mountainous area, at high altitudes, as shown in Figure 10 a and b (A – B), which intuitively correlates precipitation distribution with altitude.



a



b

Figure 10 a, b Spatial distribution of average precipitation during May - June in the RNER (1961 - 2024)

Figure 10 a-b shows a clear distribution of precipitation: the highest values are recorded in the west, in the sub-Carpathian hills and in the mountainous areas (Iezer, Poiana Stampei), where the average precipitation in May-June exceeds 170 mm. In contrast, in the eastern and southeastern parts of the region (Bârlad, Galați, Iași), average precipitation amounts fall below 150 mm, indicating a poorer rainfall regime, influenced by lower altitude and the continental nature of the climate.

6. Conclusion

The thermo-pluviometric analysis carried out for the period 1961–2024 in the North-Eastern Region of Romania highlighted the direct link between thermal and pluviometric values and the dominant physical-geographical and dynamic factors.

Air temperature shows a mathematical correlation with altitude (0.51°C / 100 m). Multi-year average values exceed 10°C in the east of the Moldavian Plain and decrease progressively towards the west, reaching approximately 1°C on mountain peaks. There are significant seasonal temperature differences: in the extreme months (January and July), the regional contrast exceeds 10°C. Thermal inversions in depressions and mountain corridors generate local microclimates. The thermal contrast between the plains and the mountains, the decrease in temperature with increasing altitude, determines large differences in the vegetation period, energy consumption, and living conditions. Thermal inversions in depressions generate episodes of persistent cold, with effects on agriculture and climatic comfort, while very hot summers in the east accentuate evapotranspiration and contribute to moisture deficiency.

As regards atmospheric precipitation, its spatial distribution is stratified (25.3 mm/100 m) and determined primarily by relief and atmospheric circulation. The highest amounts are recorded in the mountainous areas (over 1200 mm annually in Iezer), as a result of westerly circulation, orographic damming, and the advection of moist air masses that condense on exposed slopes. In the low-lying regions in the east, precipitation falls close to the threshold of 500 mm per year, confirming the continental nature and vulnerability of this sector to rainfall deficits. Seasonal differences are pronounced: minimums occur in the winter months and maximums in May–June, when convective processes and oceanic air intrusions from the west intensify precipitation. Seasonal variability in precipitation, with maximums in the summer months and minimums in winter, causes significant fluctuations in water resource availability. This directly influences agriculture (the sensitivity of crops to summer drought), the hydrological regime of rivers and reservoirs, but also the risk of extreme phenomena, such as torrential floods during the summer.

The results of this study were interpreted in the context of limitations related to the number of meteorological stations whose data were used. Although we aimed for the stations to be spatially uniformly distributed, for a more detailed interpolation of the data, we propose to implement in future research two more stations in the mountainous area and its vicinity, in order to avoid possible discontinuities. The Regression–Kriging method was used in the analysis of the spatial distribution, complemented by ordinary Kriging to reduce errors and local variations. However, the lack of microclimatic factors such as: the effect of urbanization, the exposure of the slopes, the foehn effect, may influence variations on some surfaces of the studied region. In order to highlight these particularities, it is necessary to use more complex interpolation methods, which will represent future research directions. We also propose to carry out a more detailed analysis of the temporal distribution of recorded thermo-pluviometric parameters, complemented by prognostic models, to estimate future trends, aspects that also represent directions for further research.

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