Preliminary research on thermal inversions occurring in the Northeast Region of Romania

Recherches préliminaires sur les inversions thermiques se produisant dans la région du Nord-Est de la Roumanie

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ABSTRACT: This study represents preliminary research on thermal inversions in the Northeast Region of Romania (RNER). Thermal and hygrometric monitoring was carried out in six areas (with two pairs of observation points each – one located in a depression/valley; the other on a neighbouring hill/peak), where sensors were installed in special shelters to record hourly temperature and relative humidity data between 01.01.2025 and 10.03.2025. Of the six areas studied, the thermal inversions with the highest frequency, duration, and intensity occurred in the Vatra Dornei depression (52.6% of the total hours recorded), and those with the lowest frequency, duration, and intensity occurred in the Târgu Ocna depression (7.7% of the time). The most favorable hours for the occurrence of the inversion phenomenon were 6:30 p.m. to 9:30 a.m. The high frequency and intensity of thermal inversions generate varying degrees of meteorological and climatic risk, discomfort for people, and disruption to socio-economic activities.

KEY WORDS: Temperature inversions, climate risks, Northeast Region, Romania.

RÉSUMÉ: Cette étude est une étude préliminaire des inversions thermiques dans la région Nord-Est de la Roumanie (RNER). Une surveillance thermique et hygrométrique a été réalisée dans six zones (avec deux paires de points d'observation chacune – l'une située dans une dépression/vallée, l'autre sur une colline/sommet voisin), où des capteurs ont été installés dans des abris spéciaux pour enregistrer les données horaires de température et d'humidité relative entre le 01/01/2025 et le 10/03/2025. Parmi les six zones étudiées, les inversions thermiques présentant la fréquence, la durée et l'intensité les plus élevées se sont produites dans la dépression de Vatra Dornei (52,6 % du total des heures enregistrées), et celles présentant la fréquence, la durée et l'intensité les plus faibles se sont produites dans la dépression de Târgu Ocna (7,7 % du temps). Les heures les plus favorables à l'apparition du phénomène d'inversion étaient de 00h30 à 09h30. La fréquence et l'intensité élevées des inversions thermiques génèrent des risques météorologiques et climatiques à des degrés divers, des désagréments pour les personnes et des perturbations des activités socio-économiques.

MOTS CLÉS : Inversions de température, risques climatiques, région Nord-Est, Roumanie.

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1. Introduction

In the geographical area in question, there are numerous meteorological risks, which occur throughout the year. Theoretical and applied studies on climate risk phenomena, with more or less detailed references to the phenomenon of thermal inversion, have been carried out over time by Croitoru (2003), Moldovan (2003), Bogdan (2004, 2005), Grecu (2009), Tișcovschi (2022), Mihăilă et al. (2022). Climate and climate risk research covering parts of the study area and making more detailed or more limited references to thermal inversions has been carried out by Mihăilă (2004, 2006), Tanasă (2011), Piticar (2013), Sfîcă (2015), and Ilie (2018).

Thermal inversions can also be observed in the distribution of vegetation (Ciutea and Jitariu, 2020). The inversion phenomenon temporally and spatially differentiates the occurrence of phenological phases of the vegetation of an area (on the bottom of depressions, leaf fall in deciduous trees occurs earlier in autumn compared to nearby slopes, unaffected or less affected by inversions). Thermal inversions can be determined more precisely by calculating the differences in temperature values between two monitoring points located at different altitudes (Moldovan, 2003), but also by analyzing the differences in relative humidity values (Bărcăcianu et al., 2016).

From a synoptic point of view, temperature inversions form when the baric regime is anticyclonic (Bogdan and Niculescu, 1999), as cold air masses are difficult to displace and inversions persist for many days. The cold spells typical of January and February favor the occurrence of very intense thermal inversions, with very low temperatures. Low-pressure areas are most affected by very intense thermal inversions, with cold air masses remaining in the depression basin. In addition to the very low temperature, another major problem is the pollutants retained in the inversion air mass, with air quality being significantly affected (Wallace et al., 2010; Widawski, 2015; Sfâcă et al., 2018; Niedźwiedź et al., 2021; Sadar, 2022; Piringer et al., 2024).

The phenomenon of thermal inversion, due to its characteristics: intensity, duration, or frequency of occurrence, can in certain situations have a high risk potential (Bogdan and Niculescu, 1999). Research focusing on thermal inversions has been carried out in a few national or regional climate studies. For example, thermal inversions in the Moldavian Subcarpathians have been studied in greater depth by Apostol (2004). Other studies have focused on inversions south of the Carpathian Mountains (Bărcăcianu and Apostol, 2015) or those in the lower Prut basin (Șoitu et al., 2016). Particularities of the thermal inversion phenomenon in the Rădăuți depression area were studied by Apăvăloae et al., 1987. The analysis of thermal inversions in the Câmpulung Moldovenesc Depression was carried out by Erhan (1981) and Apăvăloae et al., 1996. In the Moldova region as a whole, thermal inversions were addressed by Apostol et al. (2015). Ichim (2014a, 2014b, 2015) analyzed the thermal inversions between the Siret and Prut rivers. Nistor (2014) conducted research on temperature inversions in the Siret Valley, which crosses the aforementioned geographical sub-unit, in his doctoral thesis focused on the Suceava Plateau. Culoarul Siretului și inversiunile de temperatură din lungul său au fost cercetate și de către Sfîcă (2015, 2020). This study analyzes the thermal inversions produced in the Northeast Region of Romania (RNER) between January 1, 2025, and March 10, 2025. *The main purpose* of the research is to establish concrete, quantitative spatial and temporal parameters of temperature inversions in the RNER. *The objectives of the study* are i*)* to represent the interdiurnal air temperature regime on pairs of two points in order to capture the differences in their temperature values and inversion situations, taking into account the geographical location of the pairs of points, *ii)* establishing the intensity of the inversion phenomenon on pairs of points in accordance with their specific geographical setting, *iii)* outlining the diurnal regime of the inversion phenomenon, and *iv)* addressing the most relevant cases of inversions during the analyzed period, explaining the geographical and synoptic context of their occurrence. Compared to other studies written on the topic of temperature inversions, this one has as a novelty a multiple analysis on paired points at the hourly level of the thermal situation. Another new element is the longer monitoring period. Also, the analysis points cover the physical-geographic complexity of the RNER, being located both in the mountainous area, in the plateau area, and in the hilly area.

2. Study area

The study is territorially framed by the administrative boundaries of the RNER, which include the counties of Suceava, Botoșani, Neamț, Iași, Bacău, and Vaslui (Figure 4). The 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, Bistrița-Năsăud, Mureș, and Maramureș to the west.

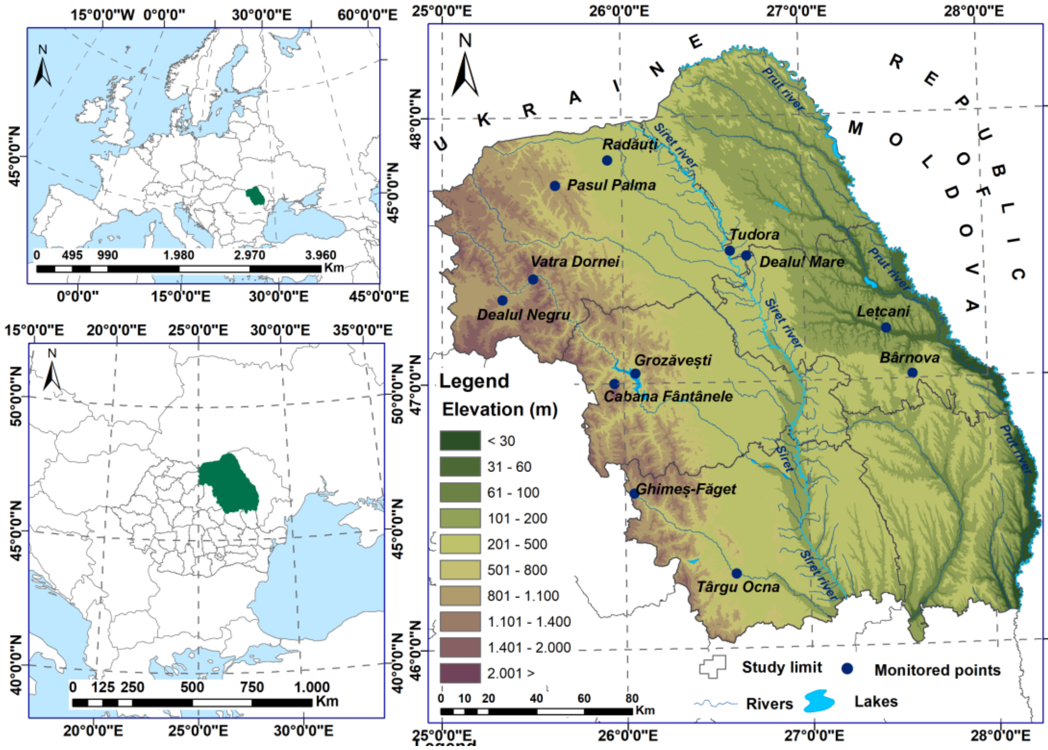

Figure 1 Study area.

The territory in which this study is implemented is complex in terms of geographical components. It includes all types of relief, from mountains to plateaus, hills, or plains, with altitudes exceeding 2,000 meters or falling below 30 meters. The most important watercourses are the Siret and Prut rivers, but also their main tributaries, such as Suceava, Moldova, and Bistrița for the Siret, and Jijia and Bahlui for the Prut. The largest reservoir in Romania (Izvorul Muntelui) is located in the studied territory. From a climatic point of view, the region has a temperate transitional climate with a clear vertical stratification. According to Tempo Online, 3,974,110 people lived in the RNER on July 1, 2024 (based on place of residence). The position of the six pairs of points was chosen to capture the formation and specificity of thermal inversions that occur in a wide variety of landforms, such as: wide depressions open to the continental space in winter – the Moldavian

Plain, the Rădăuți Depression, wide valley corridors – the Siret Corridor, intramountain depressions – the Dornelor Depression, elongated depression areas along valleys – the Trotuș Valley and the Tg. Ocna Depression, Carpathian valleys with reservoirs bordered by steeper mountain slopes – the Bistrița Valley with the Izvorul Muntelui reservoir.

3. Methods

The study began by identifying representative points in the geographical terrain for the analysis of temperature inversions. The next step was to build weather shelters, purchase sensors and place them in selected points in the study area (Figure 3).

Figure 2 CEM DT-171 sensor.

Figure 3 Weather station – Fîntânele.

The weather shelters are located in pairs, depending on altitude, in order to capture the thermal and hygrometric differences between the pairs of target points. The study includes six pairs of two points: one located in a depression or valley region, lower down, the other located higher up on a slope, saddle, or higher hilly/mountainous promontory. A first group of points targets the monitoring of thermal inversions in the Rădăuți Depression, and the weather station located in Pasul Palma was chosen as their reporting point. The second group of points consists of the Tudora station located on a terrace bordering the main bed of the Siret River, and the reporting point for this is the meteorological station in Dealul Mare. A third group of points analyses the thermal inversions that occur in the Vatra Dornei depression, and the altitude reference point chosen for reporting is Dealul Negru. The fourth group consists of the Lețcani station located at the southern end of the Moldavian Plain near the main bed of the Jijia River, with the meteorological station on Dealul Bârnova as its reporting point. A fifth group of points consists of the Grozăvești station on the shore of Lake Izvorul Muntelui, and its reporting point is the meteorological station at Cabana Fântânele in the Ceahlău Massif. The sixth group consists of the Târgu Ocna station located at the southeastern end of the Trotuș Valley, with the meteorological station near the Ghimeș-Făget Pass as its reporting point (Table 1). The altitudes at which the sensors are installed vary, reflecting the complexity of the study area. The highest monitoring points are Dealul Negru (1255 m), Cabana Fântânele in the Ceahlău Massif (1220 m), and the Palma Pass (Ciumârna) at an altitude of 1091 m. The points located at the lowest altitudes are: Lețcani (66 m), Tudora (Siret river terrace) at an altitude of 229 m, Târgu Ocna (258 m), or in the Rădăuți depression at an altitude of 369 m (Table

1). A CEM DT-171 sensor (Figure 2) was installed in each shelter located in the territory (Table 1, Figure 3), which recorded the hourly temperature, relative humidity, and dew point temperature between January 1, 2025, and March 10, 2025. These sensors stored the recorded data, which was then downloaded using the Datalogger Graph software.

Table 1 Location of monitoring stations* for thermal inversions in the RNER.

Pair of points taken into analysis	Monitoring point	Latitude	Longitude	Altitude
1	Radăuți	47°50'25"N	25°55'17"E	369 m
	Palma Pass	47°44'46"N	25°37'42"E	1091 m
2	Tudora	47°29'36"N	26°35'45"E	229 m
	Dealu Mare	47°28'24"N	26°41'15"E	447 m
3	Vatra Dornei	47°20'23"N	25°21'56"E	826 m
	Dealul Negru	47°18'57"N	25°20'01"E	1255 m
4	Lețcani	47°11'19"N	27°27'01"E	66 m
	Bârnova	47°00'59"N	27°35'19"E	359 m
5	Grozăvești	47°02'12"N	26°03'47"E	600 m
	Fântânele Cabin	46°59'56"N	25°56'49"E	1220 m
6	Târgu Ocna	46°16'45"N	26°35'53"E	258 m
	Ghimeș Făget	46°35'09"N	26°03'02"E	748 m

**Pairs of weather stations are ordered by latitude; within each pair, the first station is the one located at a lower altitude.*

To identify *hourly cases of thermal inversion,* we considered the following case study for each hourly interval:

a) (Air temperature at the lower point – Air temperature at the higher point) > 0°C **[1]**

as a case of normal thermal stratification,

b) (Air temperature at the lower point – Air temperature at the higher point) = 0°C **[2]**

as a case of indifferent thermal stratification (isothermy),

c) (Air temperature at the lower point – Air temperature at the higher point) < 0°C **[3]**

as a case of reverse thermal stratification (inversion).

The frequency of inversion hours was determined as absolute frequency (total number of inversion hours out of the total number of observation hours) or relative frequency (by reporting the total number of inversion hours to the total number of observation hours, the result being multiplied by 100). Thermal inversions were classified according to their intensity using the criteria in Table 2.

Table 2 Classification of thermal inversions according to their intensity (Mihăilă et al., 2006).

Type of inversion by intensity	Weak intensity inversions	Medium intensity inversions	High-intensity inversions	Very strong inversions
Positive temperature jump between the lowest and highest points	temperature jump between 0.1 and 3.0°C	temperature jump between 3.1 and 5.0°C	temperature jump between 5.1 and 10.0°C	temperature jump (>10.0°C)

The intensity of thermal inversions was classified into four classes, starting from weak, medium, high, and very high intensity of occurrence (Table 2).

4. Results and discussion

4.1. Interdiurnal air temperature regime by pairs of points and temperature inversions

The analysis of the interdiurnal temperature regime was the starting point for the analysis. The differences in temperature regime between pairs of stations are due to elements of the natural environment, with the relief having a direct influence on them (Bâzâc, 1983). The data presented in Figures 4, 5, and 6 show the air temperature regime from January 1, 2025, to March 10, 2025, for pairs of stations. The cold season, due to its particularities (Mihăilă and Tănasă, 2006), has a special character in supporting the occurrence of thermal inversions. The analysis of the interdiurnal temperature regime at the monitoring points located in the RNER was carried out according to the relief level in which they are located, with the analysis focusing on certain groups of points.

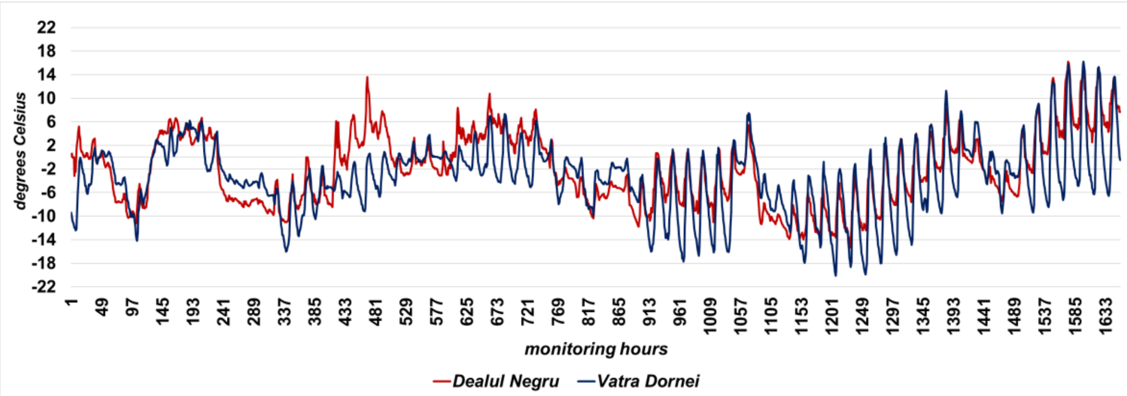

Figure 4 Inter-hourly and inter-daily air temperature regime (January 1, 2025 ÷ March 10, 2025) at the Vatra Dornei and Dealul Negru weather stations located in the middle of the mountainous area.

From the synchronous observations (one monitoring point in the depression and another on a nearby mountain), we noticed a temperature regime at the two points that differed primarily in value from that of the other pairs of stations. In the depression, at Vatra Dornei, at 826 m, the minimum temperature for the period studied was -20.1°C. The minimum temperature recorded at the monitoring point located at 1255 meters, on Dealul Negru, was -15.3°C. Figure 4 shows the interdiurnal temperature fluctuations for the two points. They are more orderly in Vatra Dornei in the depression and less orderly on the nearby peak. Interdiurnal temperature variability is also lower on Dealul Negru, due to more active air dynamics.

In the Rădăuți depression, during the monitoring period, the minimum temperature dropped to -12.9°C (Figure 5). In Pasul Palma (Pasul Ciumârna), the minimum temperature dropped slightly more, reaching -13.1°C. The synchronism of the temperature variation curves can be observed, but also the differences in values between them, given by the geographical context of the location of the two points, but also by the synoptic context.

On a lower relief step in the plateau (Figure 6), even though the temperature contrast between the bridge pairs is much lower, the minimum temperatures occur mainly in the valley or in the depressions. On Dealul Mare, the minimum temperature for the period was -10.3°C, and on the terraces of the Siret River, in the commune of Tudora, the minimum temperature was -13.1°C. The meteorological situation is similar on the contact between the Moldavian Plain and the Iași Coast (in Bârnova, the minimum temperature for the period was -11.0°C, and in Lețcani, it was -12.9°C).

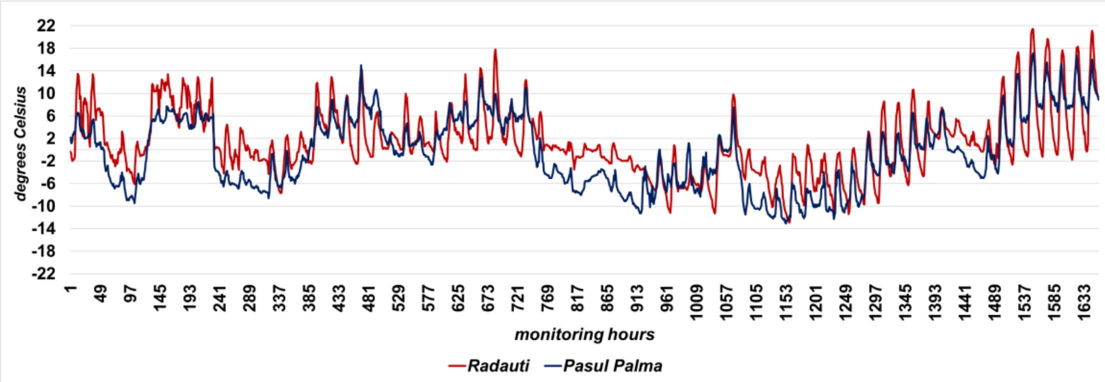

Figure 5 Inter-hourly and inter-daily air temperature regime (01.01.2025 ÷ 10.03.2025) at the Rădăuți and Pasul Palma weather stations located in the Suceava Plateau and Obcina Mare, respectively.

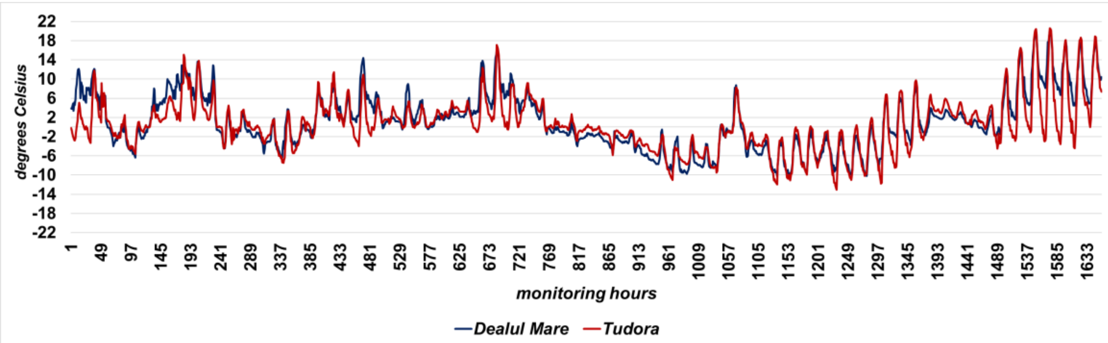

Figure 6 Inter-hourly and inter-daily air temperature regime (01.01.2025 ÷ 10.03.2025) at the Tudora and Dealul Mare weather stations located in the Siret corridor and on Dealul Mare.

At the points monitored for the specified time interval, the maximum temperature rose to 21.2°C in Grozăvești in the mountainous area, 21.4°C in Rădăuți in the plateau area, and 22.4°C in Lețcani in the plain area.

The inter-hourly and inter-daily regime of thermal inversions depends on the thermal stratification between the analyzed pairs of points. Radiative factors, atmospheric dynamics, and physical-geographical factors influence the occurrence and duration of temperature inversions. In addition to the factors mentioned, the particularities of the relief play a very important role in the generation and intensification of thermal inversions (Bogdan et al., 1971). Current climate change with a tendency for temperatures to rise (Jones et al., 1999; Ji et al., 2014; Strătilă et al., 2021; Mihăilă et al., 2022; 2024; Manea et al., 2024) lead to changes in the parameters of thermal inversions.

To identify the hours with temperature inversions in the mountainous area of the RNER, we used data downloaded from the two pairs of sensors in Vatra Dornei – Dealul Negru and Grozăvești – Cabana Fântânele.

In the first case, out of the 1656 hours of thermal monitoring of the Vatra Dornei - municipality and Dealul Negru points (Figure 7), it emerged that the Dornelor Depression was in a situation of thermal inversion stratification compared to Dealul Negru for 871 hours out of the total mentioned (52.6% of the time).

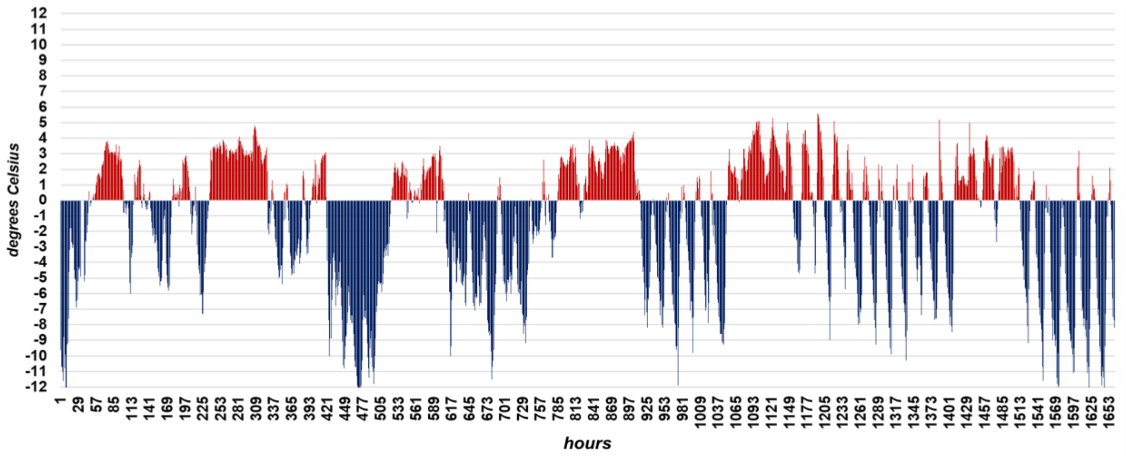

Figure 7 Sequences of hours with normal thermal stratification or temperature inversion in the Dornelor Depression (Temp. in the depression at the Vatra Dornei station < Temp. at the Dealul Negru station / temperature difference = negative) – the hourly intervals with temperature inversion are those below 0°C and are shown in blue.

In the second case monitored (the shore of Lake Izvorul Muntelui through the Grozăvești station and the slopes of the Ceahlău Massif through the Cabana Fântânele station), we noticed that above and near the surface of Lake Izvorul Muntelui, at Grozăvești, in 515 hours out of the 1,656 hours of meteorological monitoring (representing 31.1% of the total observation time), the point was in a situation of thermal inversion in relation to the marginal heights (Figure 8).

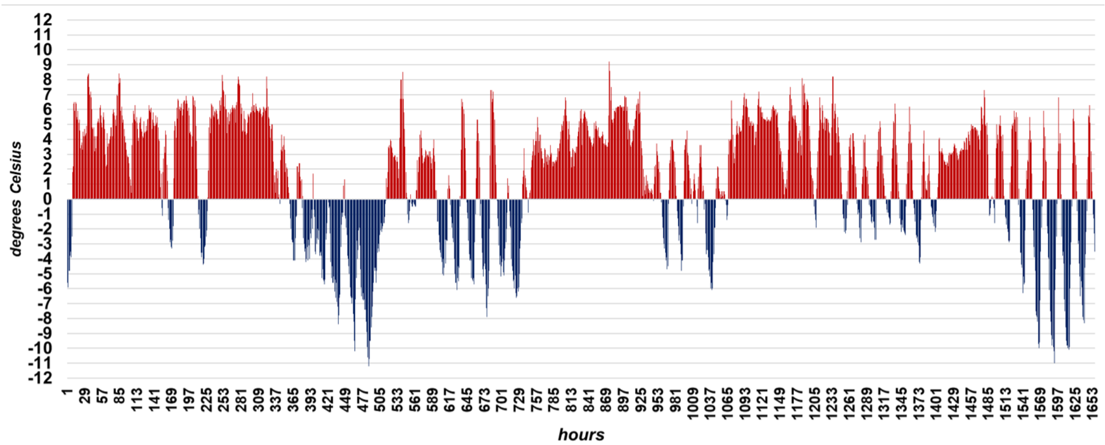

Figure 8 Sequences of hours with normal thermal stratification or temperature inversion in the area at the surface and in the vicinity of Lake Izvorul Muntelui (Temp. at the Grozăvești station on the shore of Lake Izvorul Muntelui < Temp. at the Cabana Fântânele station / temperature difference = negative) – the hourly intervals with thermal inversion are those below 0°C and are shown in blue.

The data resulting from thermal monitoring at the Rădăuți and Pasul Palma (Ciumârna) weather stations (Figure 9) show a fairly high frequency of hours with thermal inversion in the Rădăuți depression area. Monitoring at Rădăuți and Pasul Palma was carried out over an identical interval of 1656 hours. During this interval, the Rădăuți depression was in a state of thermal inversion relative to the higher point for a total of 482 hours (29.1% of the hourly cases monitored).

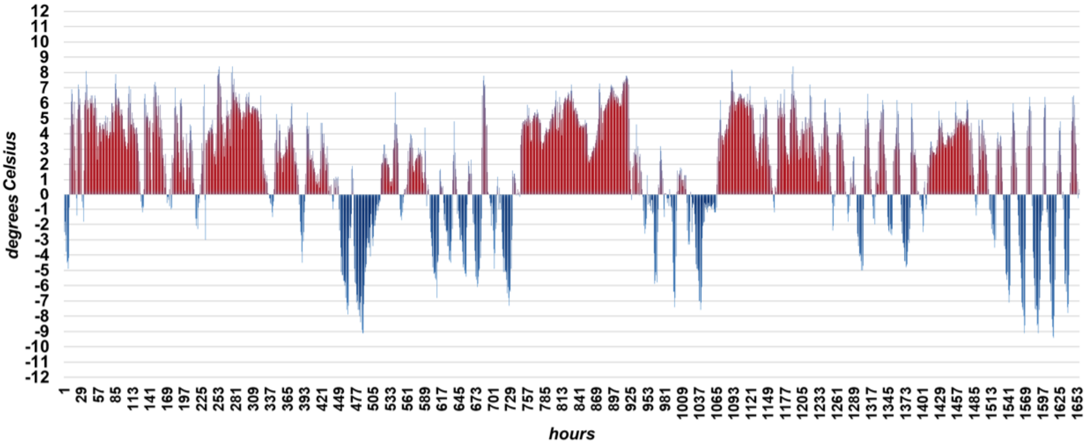

Figure 9 Sequences of hours with normal thermal stratification or temperature inversion in the Rădăuți depression area (Temp. at the Rădăuți station < Temp. at Palma station / temperature difference = negative) – hourly intervals with thermal inversion are those below 0°C and are shown in blue.

The lowest number of hours with thermal inversions, among all the pairs of points studied, with reference to the mountain level, was also recorded in Târgu Ocna (Figure 10). Their percentage was low (only 7.7%), with a total of 129 hours of thermal inversion out of the 1,656 hours monitored. The data from the Tg. Ocna station were reported to the meteorological station in Ghimeș-Făget.

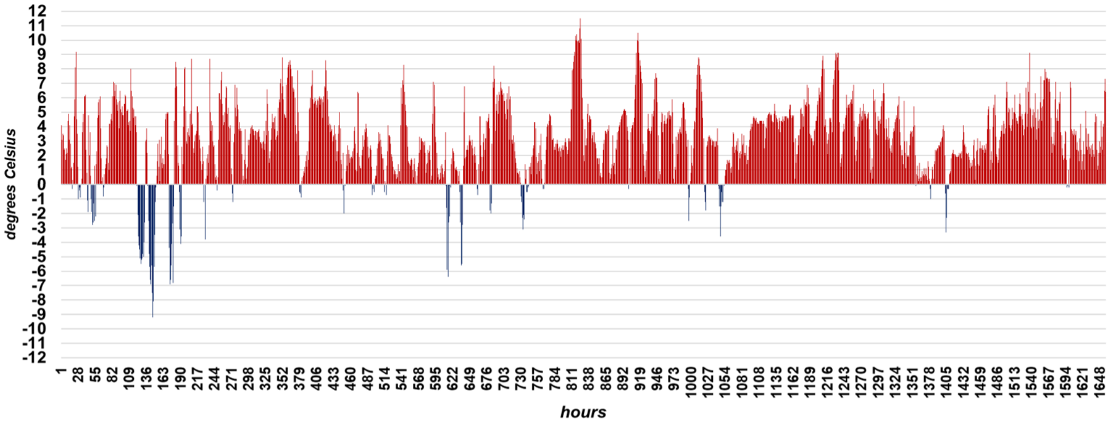

Figure 10 Sequences of hours with normal thermal stratification or temperature inversion in the Trotuș Valley, in the Tg. Ocna depression area (Temp. at the Tg. Ocna station < Temp. at the Ghimeș-Făgret station / temperature difference = negative) – the hourly intervals with temperature inversion are those below 0°C and are shown in blue.

In the depression areas and on the valleys of the plateau and hilly plain, thermal inversions occur in a smaller number of hours. Although the altitude differences between the paired points in this area are smaller, thermal inversions are not absent, and in certain meteorological circumstances they are long-lasting and have medium or high intensity.

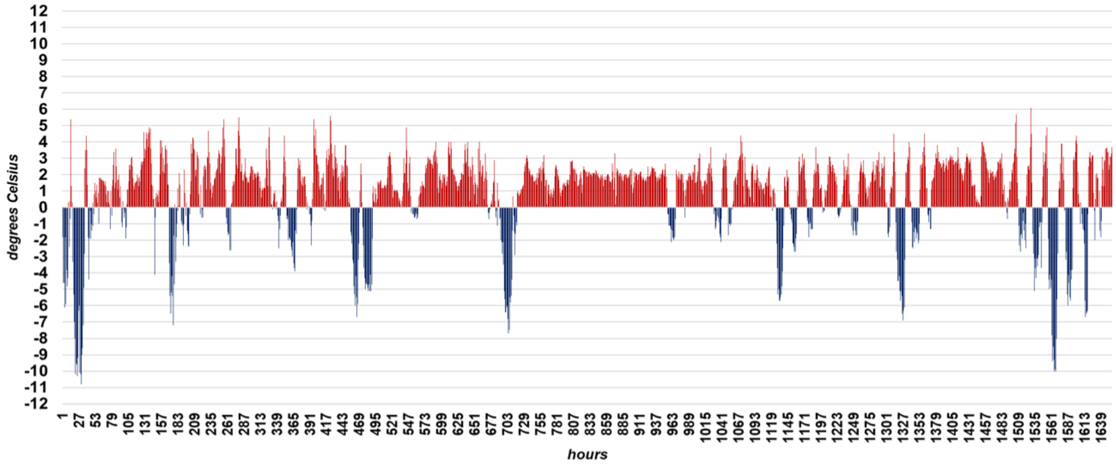

Figure 11 Sequences of hours with normal thermal stratification or temperature inversion in the Jijia Valley, southeast of the Moldavian Plain at Lețcani (Temp. at Lețcani station < Temp. at Bârnova station / temperature difference = negative) – hourly intervals with temperature inversion are those below 0°C and are shown in blue.

For example, in the comparative analysis between the Lețcani and Bârnova weather stations, the difference in altitude between them is only 293 meters. However, out of the entire monitored interval, the Lețcani station was in thermal inversion compared to the Bârnova station for 392 hours (equivalent to 23.6% of the time) (Figure 11).

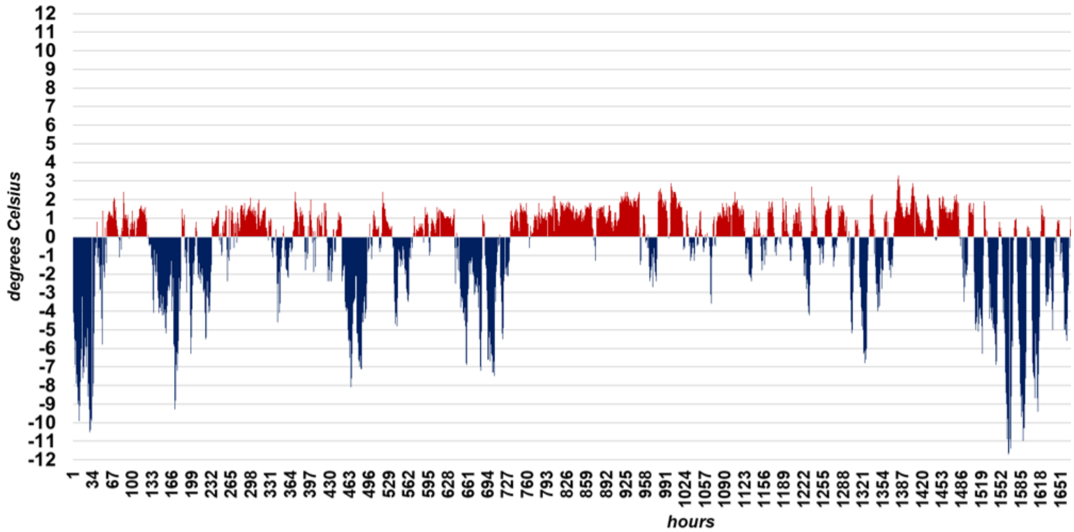

Figure 12 Sequences of hours with normal thermal stratification or temperature inversion in the Siret Valley, at Tudora (Temp. at the Tudora station < Temp. at the Dealul Mare station / temperature difference = negative) – the hourly intervals with thermal inversion are those below 0°C and are shown in blue.

The second case study of thermal inversion stratification in the plateau and hilly plains is represented by the pair of weather stations Tudora and Dealul Mare (Figure 12). Thermal monitoring was carried out in Tudora by a station located in the town of the same name on the terrace of the Siret River and another, paired station located on Dealul Mare in the eastern neighborhood. The frequency of thermal inversions in Tudora on the Siret Valley is very high. In the case of Tudora-Dealul Mare, thermal and hygric monitoring was also carried out over a period of 1656 hours. Thus, in 714 hours (43.1% of the time), the lower temperature values occurred in the Siret valley at Tudora. The difference in altitude between the two stations is 218 meters, but this altitude difference and other complementary geomorphological and physical-geographical factors were able to impose thermal inversion stratifications. Summarizing the results, we arrived at the following synthetic statistical situation (Table 3).

Table 3 Total duration of hourly monitoring intervals, duration in hours of thermal inversions, and percentage of time they accounted for of the total time allocated to observations at pairs of stations located in the RNER territory between January 1, 2025, and March 10, 2025.

Pair of points analysed	Points monitoring	Total duration of observations (hours)	Total time corresponding to inversions	
			hours	%
1	Radăuți Palma Pass	1656	482	29
2	Tudora Dealu Mare	1656	714	43
3	Vatra Dornei Dealul Negru	1656	871	52.6
4	Lețcani Bârnova	1656	392	23.6
5	Grozăvești Fântânele Cabin	1656	515	31
6	Târgu Ocna Ghimeș Făget	1656	129	7.7

Thus, most hours of thermal inversion were recorded in the Vatra Dornei depression area (52.6% of cases), followed by the atmospheric layer above and in the vicinity of Lake Izvorul Muntelui – Grozăvești (31.1% of cases), the Siret terraces - Tudora terraces (43.1% of cases), the Rădăuți – Rădăuți depression (29.1% of cases), the Jijia valley at Lețcani (23.6% of cases) and the Trotuș valley at Târgu Ocna (7.7% of cases) (Figure 13).

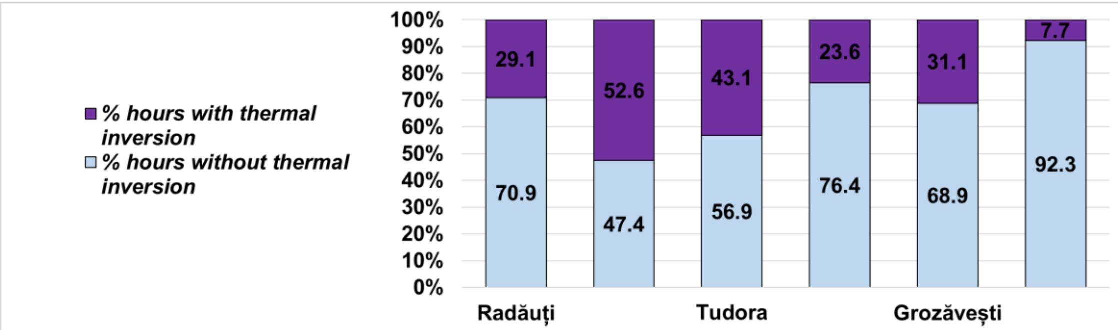

Figure 13 Percentage of hours with thermal inversion and hours without thermal inversion out of the total hours monitored at weather stations between January 1, 2025, and March 10, 2025.

At the opposite end of the spectrum, the percentage of hours without temperature inversions is 92.3% in the Târgu Ocna Depression. We also identified a high percentage of hours without temperature inversions in Lețcani (76.4%) and Rădăuți (70.9%) based on our calculations.

4.2. Determining the intensity of the inversion phenomenon based on pairs of points in accordance with their specific geographical context

The intensity of the thermal inversion phenomenon reaches different levels depending on the specificities of the geographical setting. In the analysis performed, at all monitored stations, the highest percentage is attributed to the class of weak inversions (Figure 14). The percentage of high-intensity thermal inversions is distributed as follows: Vatra Dornei (37.9%), Grozăvești (23.9%), Rădăuți (24.3%), Lețcani (18.1%), Tudora (18.1%), and Târgu Ocna (16.3%).

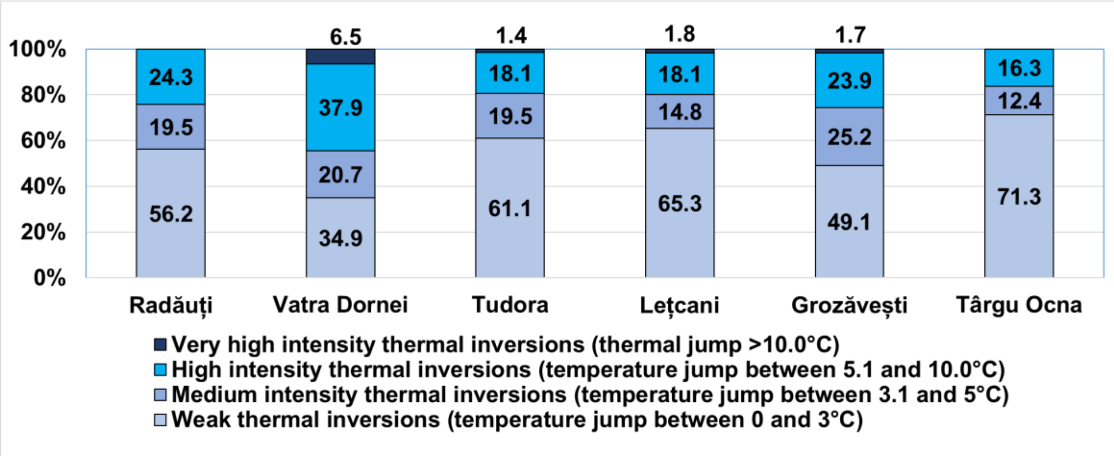

Figure 14 Percentage classification by intensity class of the total time allocated to observations at pairs of stations located in the RNER territory between 01.01.2025 and 10.03.2025.

Very high frequency inversions were identified in 6.5% of cases in the Dornelor Depression. The geographical setting of the Dornelor Depression is similar to that of other depressions in the Carpathians (Giurgeu, Ciuc, Brașov) and is conducive to the more frequent occurrence of very high intensity inversions.

4.3. Hourly analysis of temperature inversions in the RNER for the monitored period

In order to observe the daily occurrence of the thermal inversion phenomenon, Table 4 shows the hourly frequency of inversions at different intensity levels. Temperature inversions occur mostly at night and in the early hours of the day. In the Rădăuți depression area, the hours with the highest percentage of thermal inversion are 5:30 and 6:30 (46.4%), and the hours with the lowest percentage of temperature inversions are 15:30 and 16:30, with 7.2% and 8.7%, respectively. For Vatra Dornei, we identified the time interval 22:30–9:30, during which over 60% of hourly cases were in thermal inversion (with a maximum percentage of 68.1% at 8:30). In Tudora, the highest percentage of hours with inversion was recorded at 10:30 p.m. (58%) and 11:30 p.m. (53.6%), and the lowest percentage was recorded at 3:30 p.m. (18.8%), 2:30 p.m. (20.3%), and 1:30 p.m. (20.3%). For Lețcani, the highest hourly percentage of inversion hours was recorded at 1:30 a.m. (44.9%) and 5:30 a.m. (40.6%), and the lowest percentage at 14:30 (practically at this time of day in Lețcani there were no cases of thermal inversions). In Grozăvești, the hours with the highest percentage of inversions were 06:30 (53.6%), 05:30, and 04:30 with a proportion of 50.7%, and in Târgu Ocna, 10:30 with a percentage of only 17.4% of cases with inversion

In the Rădăuți depression area, the highest percentage is held by weak thermal inversions, which occur mainly in the afternoon (Figure 15). The medium intensity class mirrors that of low intensity, but with a much lower percentage frequency (the maximum percentage was 33.3% at 16:00). Strong thermal inversions occur mainly at night (Figure 15), with the highest percentage recorded at 2:30 a.m. and 3:30 a.m. (42.9%).

Table 4 Percentage share per hour of situations with thermal inversions in the RNER depression and valley areas monitored between 01.01.2025 and 10.03.2025.

a	0:30	01:30	02:30	03:30	04:30	05:30	06:30	07:30	8:30	09:30	10:30	11:30
Rădăuți	43.5	43.5	40.6	40.6	44.9	46.4	46.4	43.5	33.3	21.7	17.4	14.5
Vatra Dornei	63.7	62.3	63.7	63.7	65.2	65.2	63.7	65.2	68.1	63.7	49.2	39.1
Tudora	50.7	52.2	50.7	50.7	55	52.2	56.5	47.8	47.8	44.9	33.3	29
Lețcani	39	44.9	39	37.7	39	40.6	37.7	30.4	24.6	13	7.2	5.8
Grozăvești	46	46.4	47	47.8	50.7	50.7	53.6	44.9	37.7	29	18.8	11.6
Târgu Ocna	4.3	4.3	5.8	5.8	7	7.2	7.2	8.7	7.2	15.9	17.4	15.9

b	12:30	1:30	2:30	3:30	4:30	5:30	6:30	7:30	8:30	9:30	10:30	11:30
Rădăuți	11.6	10.1	10.1	7.2	8.7	11.6	21.7	24.6	29	34.8	39.1	43.5
Vatra Dornei	36.2	30.4	39.1	24.6	18.8	36.2	42	49.2	57.9	59.4	62.3	63.7
Tudora	26	20.3	20.3	18.8	26	34.8	44.9	46.4	49.3	55.1	58.0	53.6
Lețcani	7	4	0	2.9	4.3	8.7	17.4	24.6	30.4	30.4	36.2	36.2
Grozăvești	11	5.8	5.8	7	8.7	11.6	18.8	24.6	33	37.7	46.4	46.4
Târgu Ocna	8.7	10.1	5.8	5.8	4.3	10.1	8.7	7.2	4.3	2.9	2.9	2.9

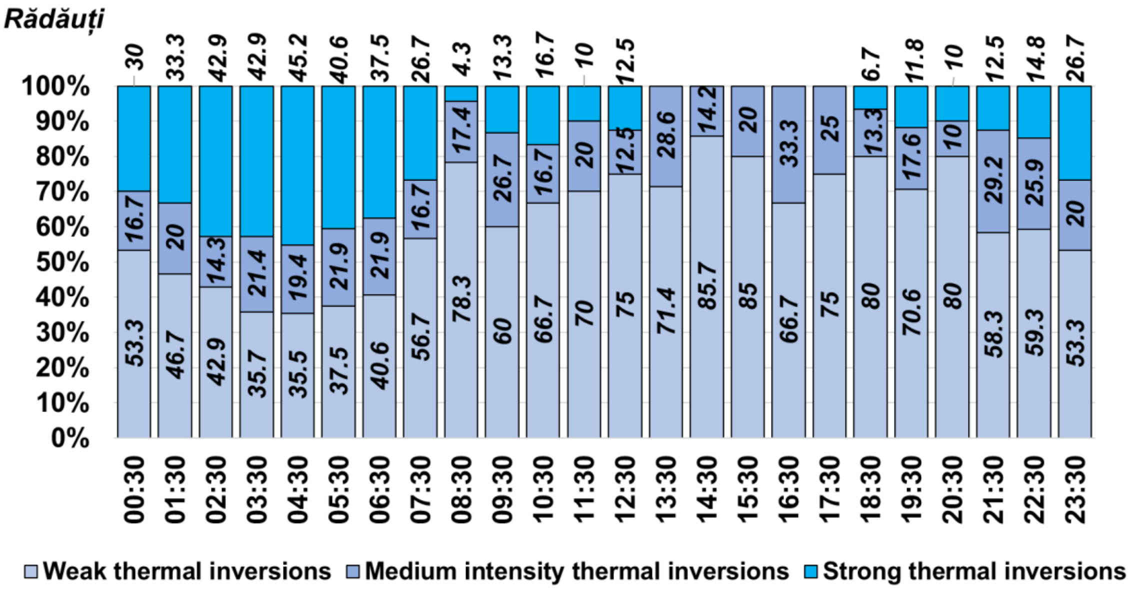

Figure 15 Hourly percentage share of thermal inversions with varying degrees of intensity in the Rădăuți depression area monitored between January 1, 2025, and March 10, 2025.

In the Dornelor Depression, the highest percentage of intensity is attributed to the class of strong thermal inversions (37.9%). These occur mainly between 00:30 and 08:30 (Figure 16), with the highest proportion of this inversion class occurring at 08:30 (61.7%), 03:30 (56.8%), 02:30 (56.8%), and 01:30 (51.2%). In this area, we also identified thermal inversions with very high intensity. The hours with the highest percentages of inversions with such intensity were 06:30 (15.9%), 07:30 (17.8%), and 08:30 (12.8%).

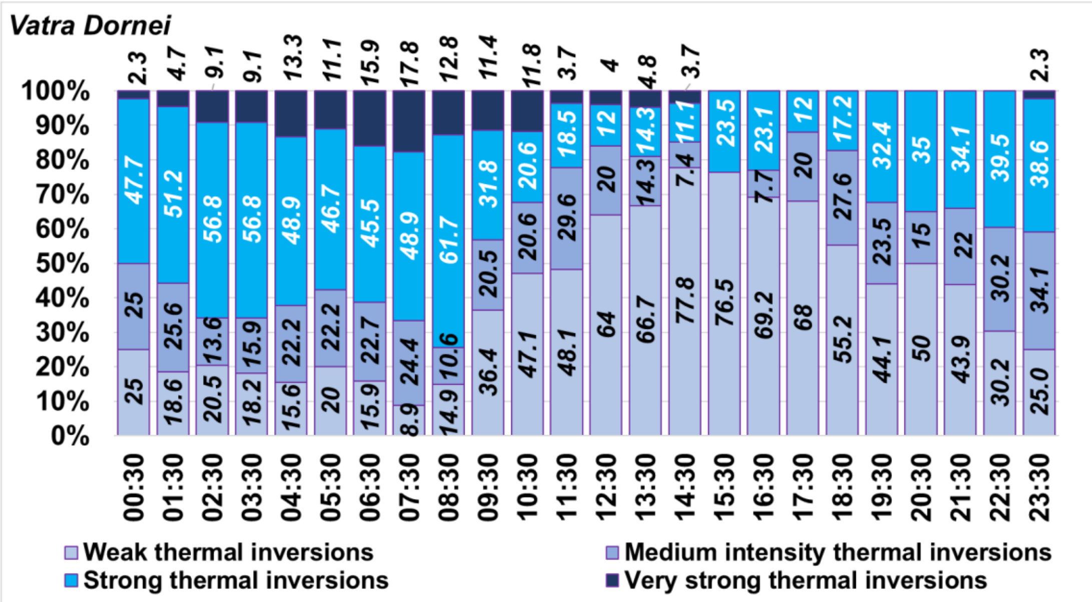

Figure 16 Hourly percentage share of thermal inversions with varying degrees of intensity in the Vatra Dornei depression area monitored between January 1, 2025, and March 10, 2025.

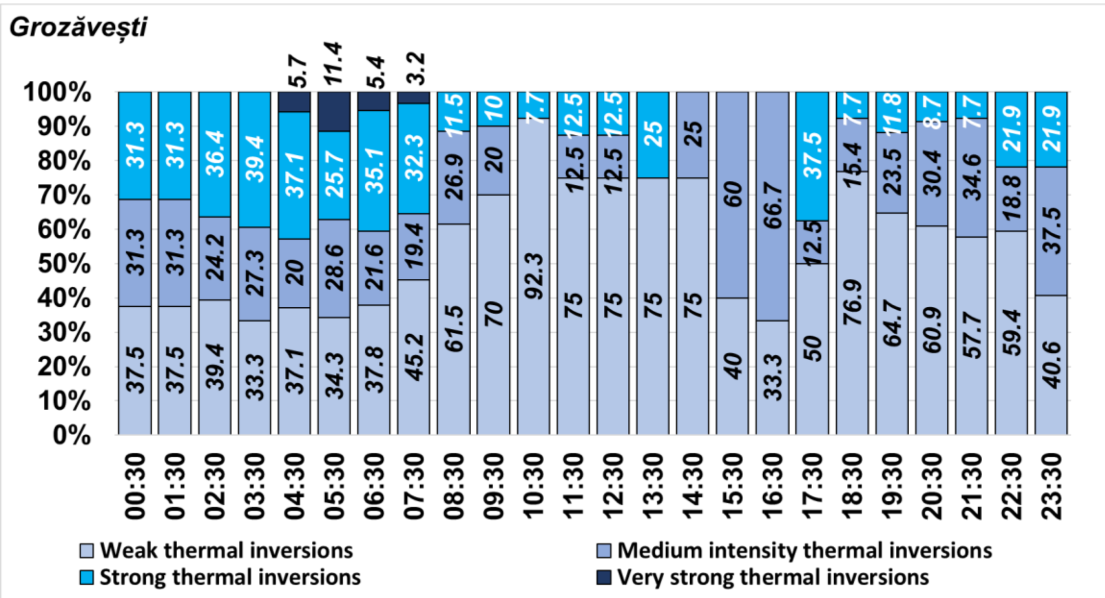

Figure 17 Hourly percentage share of thermal inversions with varying degrees of intensity in the vicinity of Lake Izvorul Muntelui in Grozăvești, monitored between January 1, 2025, and March 10, 2025.

In Grozăvești, the presence of the Izvorul Muntelui reservoir influenced the distribution of the intensity classes of the thermal inversion phenomenon. Thus, the highest frequency belongs to weak inversions (Figure 17). Medium and strong inversions have the highest percentage in the 00:30-06:30 time interval. Very strong inversions are reduced in proportion, but still occur in the 4:30-7:30 time interval. In the hilly area of Tudora, 61.1% of the total hours monitored with thermal inversion are in the low intensity class (temperature jump between 0.1 and 3.0°C). The hours with the highest percentages of inversions in this class are between 14:30 and 19:30. Medium intensity inversions accounted for 19.5%, and those with high intensity are close in percentage (18.1%). The very strong inversion class accounts for only 1.4%.

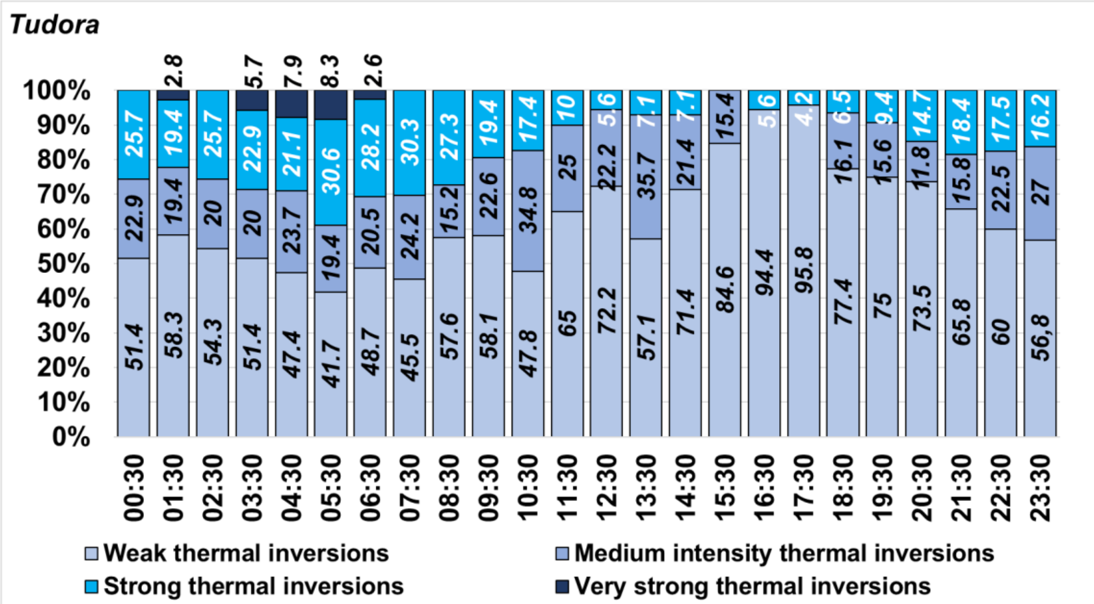

Figure 18 Hourly percentage of thermal inversions with different degrees of intensity in the Siret River valley in the commune of Tudora, monitored between January 1, 2025, and March 10, 2025.

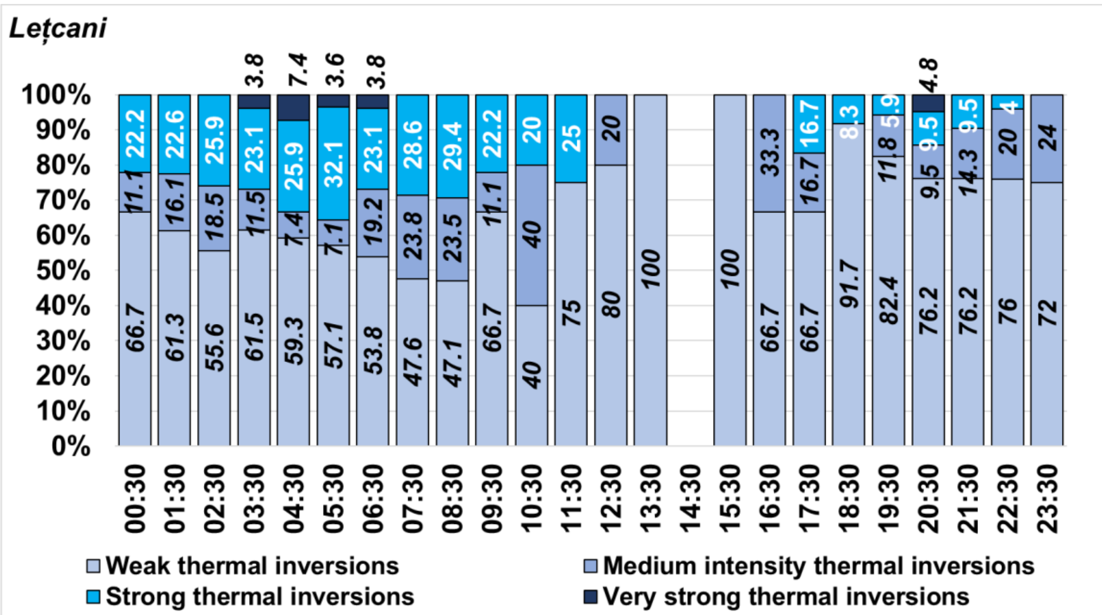

Figure 19 Hourly percentage share of thermal inversions with varying degrees of intensity in the Jijia Valley, southeastern Moldavian Plain at Lețcani, monitored between January 1, 2025, and March 10, 2025.

For both the medium and strong inversion classes, the hours with the most favorable conditions for their occurrence are in the morning (Figure 18). The distribution of intensity in Lețcani, on the Jijia Valley, is similar to the case study in Tudora. The differences in the percentages of the intensity classes are small compared to those analyzed in the Siret Valley (Figure 19).

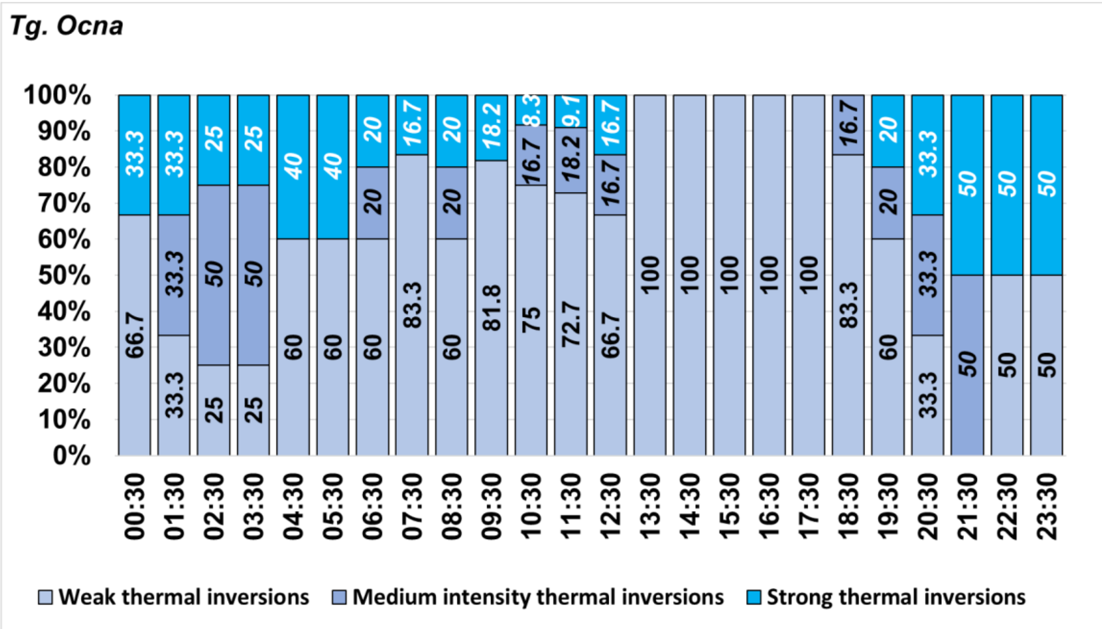

Figure 20 Hourly percentage share of thermal inversions with varying degrees of intensity in the Târgu Ocna depression area monitored between January 1, 2025, and March 10, 2025.

Of all six areas analyzed, the Târgu Ocna depression recorded the fewest inversions, and the analysis of their production intensities highlights the highest percentage for weak inversions. The hours with the strongest inversions are 9:30 p.m. (50%), 10:30 p.m. (50%), 11:30 p.m. (50%), 4:30 a.m. (40%), and 5:30 a.m. (40%). In this area, very strong inversions were not recorded during the monitored time interval (Figure 20).

4.4. Distribution of air temperature during thermal inversions in the study area for several consecutive days of temperature inversion

From the research conducted, we identified situations in the study area where temperature inversions persisted continuously for several days. In Figure 21, we have mapped three such situations. The first interval studied was January 26–January 31, the second interval studied was February 24–February 27, and the third interval covered the days of March 5–March 9, 2025. We calculated the average temperature differences that indicate the thermal inversion phenomenon for the three periods studied, thus observing differences between the monitoring points.

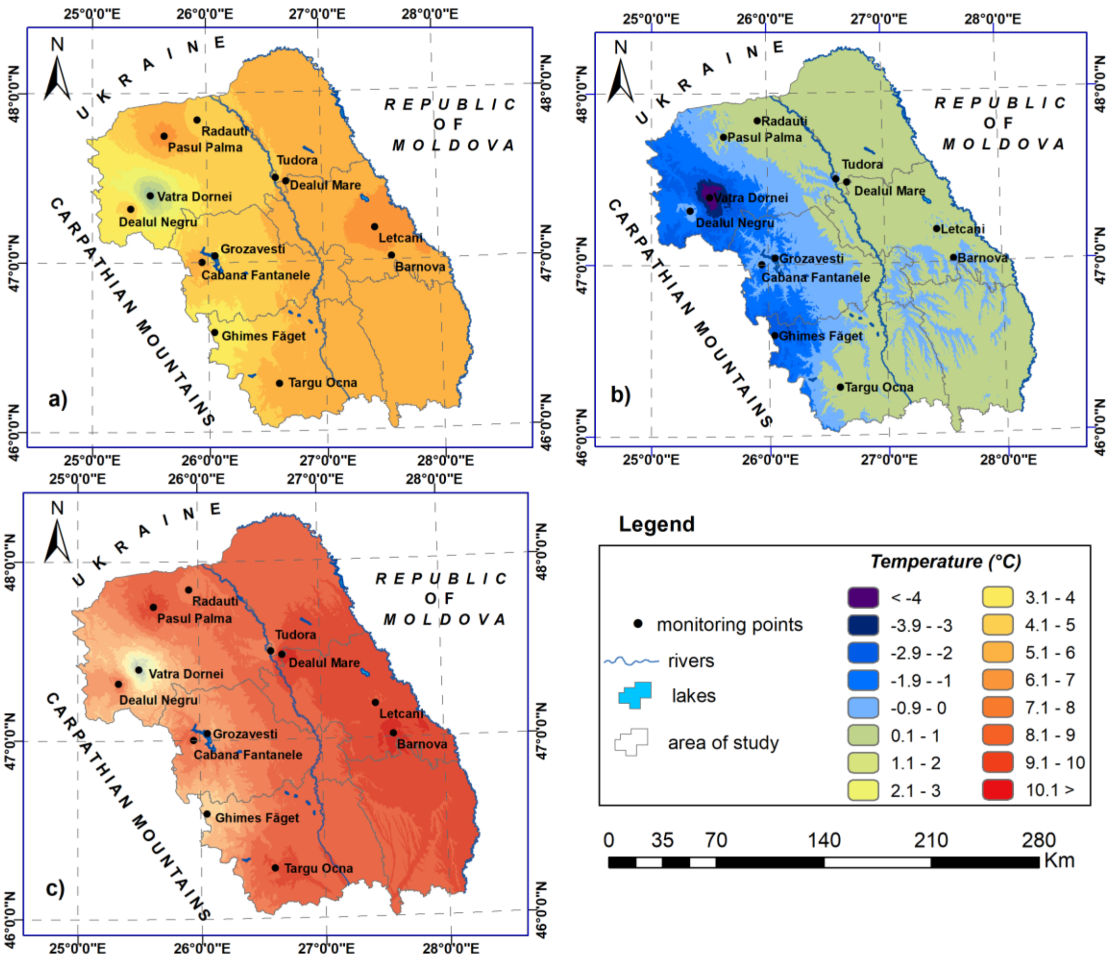

Figure 21 Cases of thermal inversions that are more representative in terms of duration in the RNER during the studied period: a) January 26–January 31, 2025; b) February 24–February 27, 2025; c) March 5–March 9, 2025.

It is particularly noticeable that, across the entire territory of the RNER, inversions occur mainly in the low-lying areas in the north-west of the area, the most representative being those affecting the Dornelor Depression, Rădăuți, the shore of Lake Izvorul Muntelui, and the terraces/valley of the Siret River.

5. Conclusion

The interdiurnal air temperature regime in the study area, during the analyzed time interval, recorded fluctuations depending on the weather and the influence of the local geographical setting on the physical parameters of the atmosphere. In the mountainous area, the temperature rose to 21.2°C, and the minimum recorded dropped to -20.1°C. In the submountainous zone, the maximum was 22°C, and the minimum dropped to -17.8°C. In the hilly area, the maximum temperature was 22.4°C, and the minimum recorded by was -13.1°C. The thermal inversion phenomenon occurred with differences between the pairs of monitored points. Of the total hours analyzed in this study, most hours with thermal inversions occurred in Vatra Dornei (52.6%), followed by the Siret Valley - Tudora (43.1%), the shore of Lake Izvorul Muntelui - Grozăvești (31.1%), the Rădăuți - Rădăuți depression (29.1%), and the Bahlui Valley - Lețcani (23.6%). The fewest hours with thermal inversions were recorded in the Târgu Ocna - Tg. Ocna depression (7.7%). Most temperature inversions occur between 6:30 p.m. and 9:30 a.m., with a number of local variations. In the analysis of the intensity of the thermal inversion phenomenon for the six pairs of points, the highest percentage belongs to the weak inversion class (34.9–71.3%). Medium intensity inversions account for between 12.4 and 25.2%. Vatra Dornei recorded the highest percentage of high intensity inversions of the total hours monitored (37.9%), and Tg. Ocna the lowest (16.3%). Very high intensity inversions were recorded in a much lower percentage: 6.5% in Vatra Dornei, 1.8% in Lețcani, 1.7% in Grozăvești, and 1.4% in Tudora. In the Rădăuți Depression and in Târgu Ocna, no very high intensity temperature inversions were recorded. Even though the observation period was relatively short, we identified periods of several consecutive days (4-6 days) that were entirely in temperature inversion situations, with varying degrees of intensity (January 26, 2025 – January 31, 2025; February 24, 2025 – February 27, 2025; March 5, 2025 – March 9, 2025). These inversions occurred in anticyclonic synoptic situations.

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