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FREQUENCY OF THERMAL INVERSIONS BETWEEN SIRET AND PRUT RIVERS IN 2013

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Abstract: Temperature inversions represent complex phenomena, specific for depression forms of relief which introduce changes in vertical zoning (Apăvăloae, Apostle, Pîrvulescu, 1986 by stable air stratification (Erhan, 1981), because of their morphological features, this is due to the interdependence of general movement and characteristics of the active surface, being the cause of their production (Apăvăloae, et. al., 1984, 1986, 1987). The generation of thermal inversions, their intensity and frequency is a consequence of altitude topography, morphology, fragmentation, orientation and degree of closure to external drives. (Apăvăloae, Apostle, Pîrvulescu, 1988). Thermal inversions represent complex phenomena, specific to depression landforms that introduce changes within the vertical zoning (Apăvăloae, Apostol, Pîrvulescu, 1986) by stable air stratification (Matveev, 1958, Erhan, 1981, Yinghui Liu, 2002) where vertical thermal gradient is negative (Matveev, 1958), due to their morphological features, also as a consequence of the interdependence of general circulation and characteristics of the active surface, the cause of their generation (Apăvăloae, et. al., 1984, 1986, 1987).

Introduction

Thermal inversions are associated with stable stratification conditions or „most stable” (Matveev, 1985), to the air in the low troposphere, persistance of atmospheric stability conditions. The increase in temperature with altitude, and various characteristics of air humidity, clouds and thermal inversions result in the formation of the inversion layer, aerosol transport and wind speed (Yinghui, Liu, 2002).

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In some conditions, thermal inversions can occur by radiative cooling, advection of warm air masses over the layer of cold air, as depression relief and and morphometry (Kahl, 1990, quoted by Liu, 2002).

Producing thermal inversions, intensity and frequency is a consequence of altitude terrain morphology, fragmentation, orientation and degree of closure to external drives (Apăvăloae, et. al., 1988).

Normally, the atmosphere is characterized by a decrease in the elevation of the air temperature, in most cases the temperature tends to rise in altitude, which is characterized by a negative or null vertical thermal gradient (Apăvăloae, et. al., 1994).

When the vertical thermal gradient is equal to 0 (zero), the air temperature is constant for a certain altitude difference isotherms are produced (Apostol, 1999), which represent „state of thermal instability of the atmosphere, neutral, have a very low statistical probability of producing, the chances of determining them being reduced, these making the transition between the inversion layer and the air layer above the normal distribution of thermal gradients (Apostol, 1999).

Depending on the formation, thermal inversion phenomena are caused by a number of global factors felt throughout the year resulting from the rotation of the Earth's radiative heat balance seasonal and/or diurnal and seasonal variation of surface characteristics underlying assets. After the formation, thermal inversion phenomena include: radiation thermal inversions, nocturnal thermal inversions, winter thermal inversions and snow (spring) thermal inversions.

2. Data and methods

The studied area is represented mostly by the area between Prut and Siret valley containing a large part of the historical province of Moldova (fig. 1).

The interest area is placed about 3 ° latitude and about 2 ° longitude, which provides a longitudinal climatic setting quite diverse.

The landscape is characterized by heights ranging between 0 m (in lower plain of Siret river and Prut river at the confluence of the Danube) and 586 m- Dealul Mare-Harlau (Peak Tudora).

Morphometric speaking, on the studied surface the most representative altitudinal class is between 100-200 m altitude, with a share of about 42.2% (Fig. 2) it is specific in the south of the territory and over watercourses. Lowest weight belongs to the altitude class which has altitudes above 500 m with a approximate rate of 0.1%, these heights being specific for Dealul Mare Hârlău and for Culmea Doroșan from Colonele Tutovei.

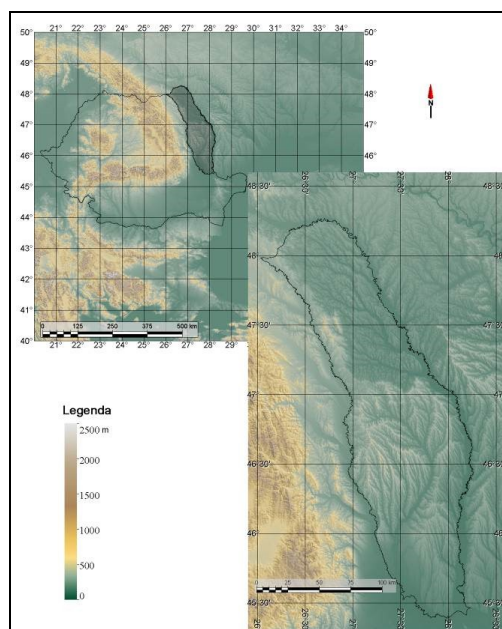


Fig. 1. Locating the study area in Romania

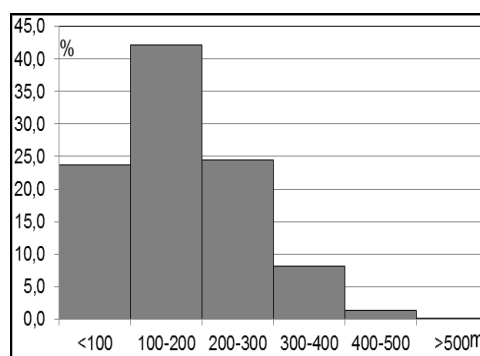


Fig. 2. The frequency distribution of elevation classes in the region between the rivers Siret and Prut

The experimental observation network includes 14 observation points including: two automatic weather stations (Cârja, and Mădârjac) and 12 data loggers (Larga Jijia, Dacia, Dancu, Ștefănești, Cîric, Răducăneni, Roșiești, Roman, Tudora, Păun, Ivănești, Deleni), (tab. 3.).

First observations were conducted in Roman region, since December 2011 and the observations were aiming just a series of experiments regarding behaviour and recording of the data loggers, battery life autonomy, real time comparison between N.M.A. data and Roman meteorological station.

Observations were also realised at a 6 hour interval for Răducăneni, Larga Jijia and Roşieşti points, starting the summer of 2011 but the data loggers functioned without meteorological shelters until November 2012. Thermal values registered were extremely high, thus forcing the team to shelter all data loggers mentioned above. V

The present study assumed at first conceiving and designing mini weather shelters similar to those used on conventional meteorological platforms, shelters in which the data loggers were installed responsible for registering air temperature and humidity values at 1 hour interval.

Tab.1. Observation points that sum up the experimental observation grid

<i>Nr. Crt.</i>	Station name	Type	ALT.	LAT.	LONG.	Functioning interval
1	Cârja	s.m.a.	21	46° 09'	28° 06'	08.2012 -> present
2	Larga Jijia	senz.	42	47° 21'	27° 22'	08.2011 -> present
3	Dacia	senz.	44	47° 10'	27° 32'	12.2012 -> present
4	Dancu	senz.	60	47° 09'	27° 40'	11.2012 -> present
5	Ştefăneşti	senz.	60	47° 50'	27° 14'	11.2012 -> present
6	Ciric (Veneția)	senz.	63	47° 09'	27° 37'	12.2012 -> present
7	Galați	S.M.	68	45° 28'	28° 02'	-
8	Iași	S.M.***	104	47° 10'	27° 37'	-
9	Răducăneni	senz*	136	46° 57'	27° 55'	06.2011 -> present
10	Roşieşti	senz.	142	46° 26'	27° 53'	06.2011 -> present
11	Botoşani	S.M.	161	47° 44'	26° 38'	-
12	Bacau	S.M.	182	46° 31'	26° 54'	-
13	Roman	senz.	205	46° 56'	26° 54'	12.2011 -> present
14	Mădărjac	s.m.a.**	252	47° 03'	27° 15'	10.2012 -> present
15	Tudora	senz.	256	47° 30'	26° 38'	10.2012 -> present
16	Păun	senz.	347	47° 05'	27° 39'	11.2012 -> present
17	Mănăstirea Ivăneşti	senz.	460	46° 37'	27° 24'	10.2012 -> present
18	Deleni	senz.	487	47° 29'	26° 50'	10.2012 -> present

*Temperature and humidity sensors

**Automated meteorological stations

***N.M.A. meteorological stations that transmit in the sinoptic international flow.

The mini shelters have reduced dimensions compared to standard one (30x30x30 cm) and are realised entirely out of wood. After installation and

assembly, two layers of white paint were applied on the outside of the shelter and of black paint on the inside.



Fig. 3. Shelter materials (left) and shelter assembly (right)

Each shelter was installed at standar height observation (2 m) on grassy and open areas, avoiding as far as possible natural shading during the day (fig.4).



Fig. 4. Mini meteorological shelter (left); Mini-shelter at 2 m standard height at Tudora, Jud. Botoșani observation point (right)

Instrumentation used. The experimental observation network includes 14 points installed by the team, to which we added the 4 weather stations that transmit in international synoptic flow. As mentioned above, the team tried a uniform coverage focused specially on a homogeneous altitudinal distribution with respect to the official meteorological network.

The altitude plateau ranging between 100- 200 m has the largest share (42.2%) within the region. In this altitude range are three weather stations that are part of the official N.M.A. and transmit hourly data in international synoptic flow. In this altitudinal range, two experimental observation points (tab.2).

Răducăneni observation point (136 m) links profile between Păun and Valea Prutului observation points.

Tab. 2. Frequency classes of altitude and the number of observation points.

Altitudinal class (m)	Frequency (%)	Number of observation point
<100	23,7	7
100 – 200	42,2	5
200 – 300	24,5	3
300 – 400	8,2	1
400 – 500	1,3	2
>500	0,1	0

Observational point Roşieşti (142 m) is located in a tightly closed micro depression, very well enclosed that is drained by Idrici river, left affluent of Bârlad river. The enclosed depression landform gives it a unique character. This observation point connects Ivăneşti and Cârja observation points.

Higher altitude levels present lower heights, but as distribution pattern regarding the thermal inversion phenomena they are considered as crucial observation points. Within the region there are three observation points at altitudes greater than 300 m.

Păun observation point operates at 347 m altitude which is considered as a junction point linking a series of profiles that we want to analyze the phenomenon of thermal inversion. It represents the bridge connecting the other observation points installed in Iassy alongside meteorological station of Iassy and Răducăneni observation point.

Ivăneşti observation point is located in Similea hills and function at 460 m altitude and it is also the link to the profile crossing from west to east the central-southern part region of the alignment Bacău – Ivăneşti – Roşieşti - Cârja.

Highest altitude observatins within the region is 487 m at Deleni observation point located in Dealul Mare- Hârlău. This point connects, in terms of

observations, the northern central part of the region. Observation points that we consider to be related are: in the north part Botoșani meteorological station, in the west Tudora observation point, north-east Ștefănești observation point and in the south-east part Larga Jijia observation point, this relationship also having the highest relative latitude of approximately 445 m.

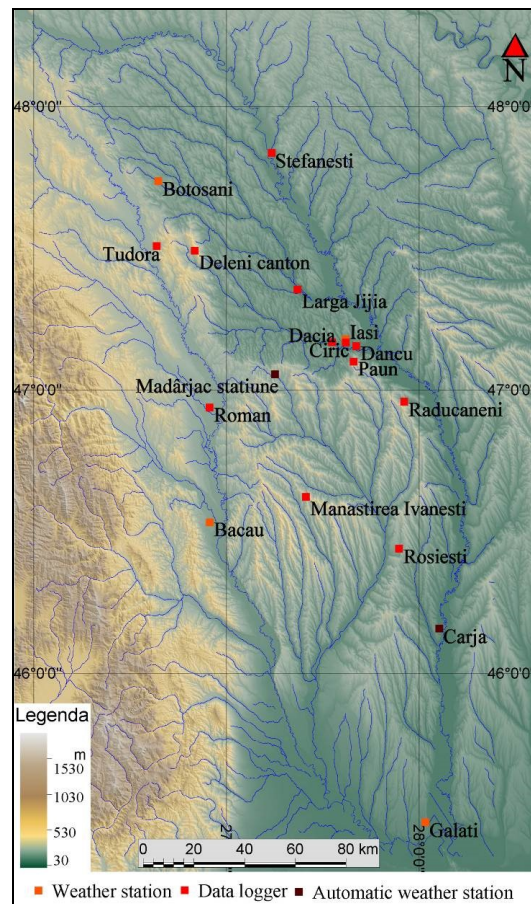


Fig. 5. Experimental observation network between Siret and Prut rivers

Cotnari observation point functions at 265 m altitude near Cotnari village. This point connects other observation points towards Siret river and Moldavia Plain, comparable with Deleni observation point.

For this study hourly data obtained in the experimental observation network were used, together with a series of common observations from 2013. The frequency of the thermal inversion phenomena were calculated for each profile.

2. Results and discussions

2.1. Annual frequency of the thermal inversion phenomena

In Romanian literature there are no works regarding thermal inversion phenomenon at hourly occurrence over a one year period of time. In most Romanian literature in which reference is made on thermal inversion phenomena they are associated in most cases with particular periods of abrupt cooling, specific to the cold semester. On an annual basis there are a series of references regarding the thermal inversion phenomenon especially in the mountain area.

High latitudinal extension of the area offers a series of thermic differences which are induced first of all in the caloric radiative balance, air mass dynamics, morphological and morphometric parameters.

Using monthly mean data one can not determine the frequency of thermal inversion phenomena, especially those relative to radiation that produce in the first part of the day and they occur for a short period of time being easily dissipated after sunrise.

The entire region is distinguished by an average frequency of thermal inversion phenomenon of approximately 24.7% (Fig. 6).

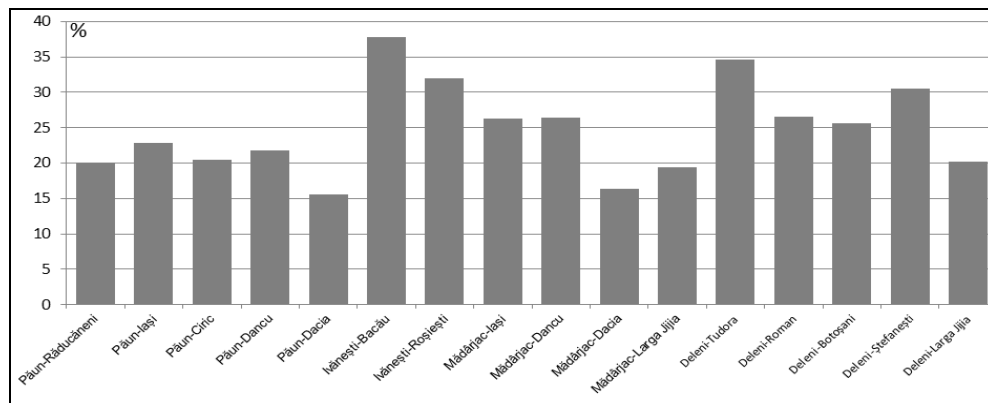


Fig. 6. Annual frequency of the thermal inversion phenomenon during 2013

For 2013 high frequencies of the inversion phenomenon are distinguished within the Siret corridor. In the year 2013, the hourly monitored inversion phenomenon present a frequency share of approximately 38% on Ivănnești-Bacău

profile but little further north on Deleni-Roman profile, where phenomenon frequency was lower, reaching a frequency of 26%. Lower inversion phenomenon frequency could be explained by the position of the observation point, that being located on the outskirts of the city. In these circumstances the heat generated by the anthropogenic surfaces is felt and it is influencing to some extent the thermic regime of this observation point. The northern part of Siret river can be distinguished through a frequency of the thermal inversion phenomenon of approximately 34% on Deleni-Tudora profile.

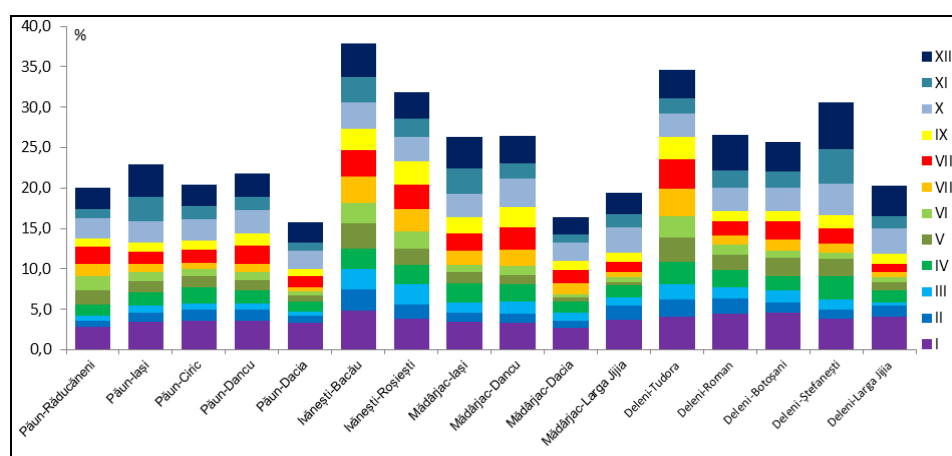


Fig. 7. Monthly frequency of thermal inversion phenomenon in 2013

Annual thermal inversions rate regime is characterised by large values mainly during the cold semester, with highest frequencies registered in January when profiles of Siret river observation points are highlighted. High frequency of situations regarding atmospheric stability conditions generated by the anticyclones baric formations determine an increase of thermal inversion phenomenon frequency specially in „closed” lowlands areas.

Within the profiles there is high frequency highlighted pertaining to the thermal inversion phenomenon during winter, especially during January and December (fig. 7).

Profiles Ivănești – Bacău, Deleni – Tudora, Ivănești – Roșiești and Deleni Ștefănești are distinguished by the highest values of thermal inversion phenomena with largest monthly values throughout the year (fig. 7).

In general, the spring season is poorly represented in the incidence of the thermal inversion phenomena except the analyzed profiles in correspondance with area of Siret river. Atmospheric dynamics is more intense during spring months

which induces turbulent mixing of air masses existing in low troposphere, greatly reducing the frequency of thermal inversion phenomena.

Daily frequency of thermal inversion was calculated based on the average daily temperature values and compared on profiles for pairs of two stations. This type of frequency highlights very well the circumstances in which the phenomenon of thermal inversion that occurred in high intensity actively influenced the thermal regime of the air temperature in certain areas.

Through morphometric and morphological particularities, corroborated with the intense foehn phenomena specific to Dealul Mare Hârlău region, the number of situations with thermal inversion with strong intensity highlights the profiles Cotnari – Tudora, Cotnari – Roman, Deleni tudora and Ivănești – Roșiești. Within these sections we can distinguish high frequency in the daily average values, both during the cold semester as well as the hot one (fig. 8).

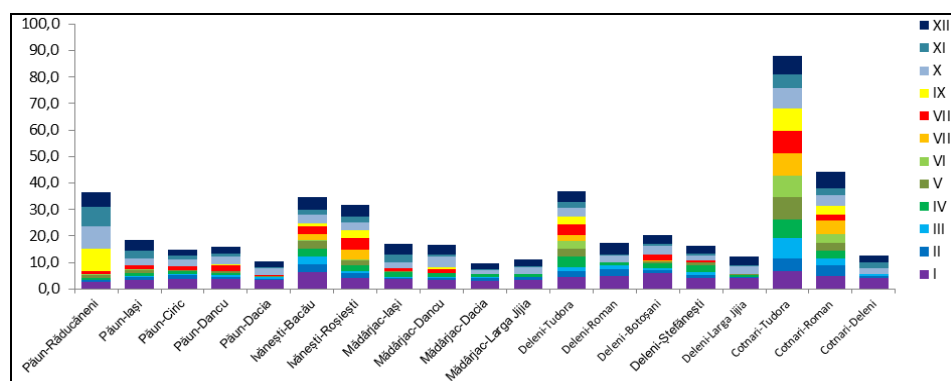


Fig. 8. Daily frequency of the thermal inversion phenomenon

The profile Păun – Răducăneni is characterized by extremely high frequencies of the year 2013 during the autumn season. The high incidence that thermal inversion phenomena generated low values for the daily average temperature of the autumn season.

Low frequencies outlined in the urban areas (Dacia observation point) and regions with large water surfaces. Although the phenomenon of thermal inversion occurs throughout the year in these profiles impact on the average daily temperature is not felt in the thermal regime.

Major differences in the evolution of thermal inversion phenomena frequency between the aisle areas, micro depression landforms and areas with a lower degree of fragmentation it can be deduced that to some extent the intensity degree pertaining to thermal inversion phenomenon. Thus, the thermal inversion episode is

intense (even if radiation is a thermal inversion), the mean temperature of that day will be lower than those recorded at higher altitudes.

2.2. Hourly frequency of the thermal inversion phenomenon

2.2.1. Thermal inversion phenomenon frequency in the interval 01:00 – 06:00 a.m. During the year, the phenomenon of thermal inversion occurs cyclically reaching maximum frequency required in the thermal regime especially during the cold semester. In the daily regime, the thermal inversion frequency is intensified during night time. Thus, between the hours 01:00 to 06:00, the frequency of the thermal inversion phenomena recorded values exceeding the average annual frequencies. In these conditions we can equally distinguish all relationship analyzed, most common being those calculated on the corresponding profiles towards Siret river, which present specific frequencies of approximately 50-55 % during 2013 between the hours 01:00 - 06:00.

The radiative inversions that manifest on the background of radiative cooling specific to the night regime induce a grow in frequency after midnight and continues to grow in frequency during the night until the early hours. Maximum frequency of manifestation for the thermal inversion occurs predominantly around 05:00. The time for maximum thermal inversion occurrence depends on the time when the sun rises, is limited by atmospheric dynamics and local peculiarities of the relief, the frequency gradually ranging from one month to another.

In the thermal inversion frequency specific for 01:00 – 06:00 interval it stands out through almost equal frequencies for each month of the thermal inversion occurrence throughout the year. Large frequencies can be observed (fig. 9 - 14) pertaining to thermal inversion phenomenon both for the cold season as well as the warm semester. High frequencies of thermal inversion phenomenon occur due to radiative cooling of the air in the immediate vicinity of the ground and especially on slopes where it becomes denser and is driven by gravity to the bottom of the valley. During situations characterized by atmospheric calm, the air is denser hence implicitly colder, it gets stratified favoring thermal inversion phenomenon occurrence.

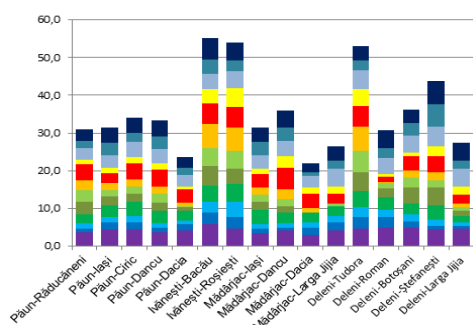


Fig. 9. Thermal inversion phenomena frequency at 01:00 a.m.

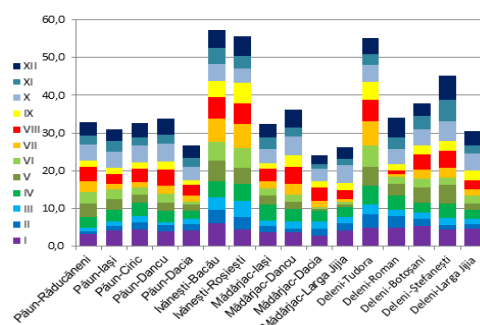


Fig. 10. Thermal inversion phenomena frequency at 02:00 a.m.

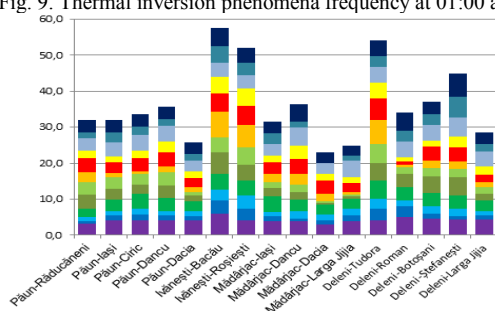


Fig. 11. Thermal inversion phenomena frequency at 03:00 a.m.

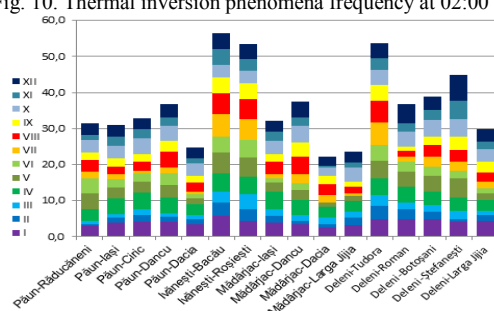


Fig. 12. Thermal inversion phenomena frequency at 04:00 a.m.

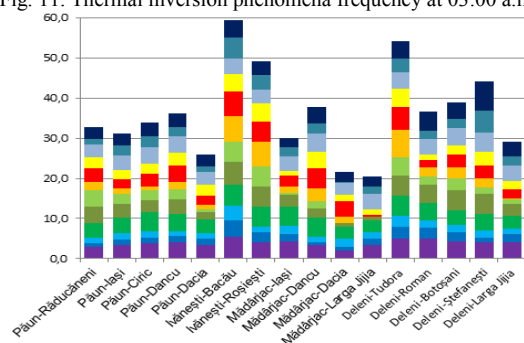


Fig. 13. Thermal inversion phenomena frequency at 05:00 a.m.

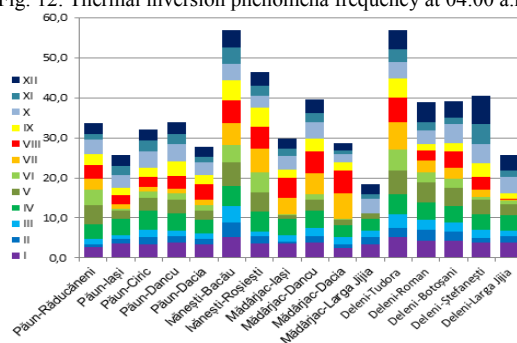


Fig. 14. Thermal inversion phenomena frequency at 06:00 a.m.

Except Siret valley areas, in the hourly development of thermal inversion we can distinguish Roșiești observation point. This closed micro-depression character offers ideal conditions for stabilization and sedimentation of cold air which remains trapped in the bottom of the valley.

Lowest thermal inversion phenomenon frequencies are characteristics to open areas with low fragmented relief. An example can be presented in the case of Larga Jijia observation point compared with Mădârjac meteorological station. The

position of the Larja Jijia observation point located inside the Larja Jijia farm induces a moderate topoclimate, specific to water accumulation. This feature determines low frequencies of thermal inversion phenomenon on this profile.

2.2.2. Thermal inversion phenomenon frequency in the interval 07:00 – 12:00 a.m. With sunrise, the thermal inversion phenomenon frequency gradually decreases. Major difference can be observed from one hour to another. Largest differences are observed in the warm semester where due to the increase of the caloric radiative flow, thermal inversions start easily to be dissipated by the ascending caloric flow.

In this frequency range the thermal inversions fall to the point where stability layer is removed. This development is felt especially when specific radiative inversions related to the summer months, leading most cases to the destruction of the horizontal inversions towards the afternoon.

We also observe it in the situation of Siret river which stands out as an area where the hourly rate decreases slowly, dropping below 30% just after 11:00. Radiative thermal inversions in the Siret river area that form during summer months especially during August, during which high levels of thermal inversion frequency are preserved.

Winter months, especially in December and January are characterized by high frequencies generated by enhanced stability situations, specific to anticyclones baric formations that impose within the thermal regime through negative air temperature values.

Thermal inversion phenomena generated by dynamic factors particularly those of frontal origin are imposed in the hourly frequencies. Thus, at 11:00 on Ivănești – Roșiești profile a total frequency of approximately 6% is observed and then again at 12:00 it can be distinguished through a frequency of about 8.8%. One can notice the increase in frequency of thermal inversion formation. The depression landform and the high degree of storage pertaining to this landform form ideal conditions related to preserving the cold air masses within the landform, very difficult to dislodge the warm front passage.

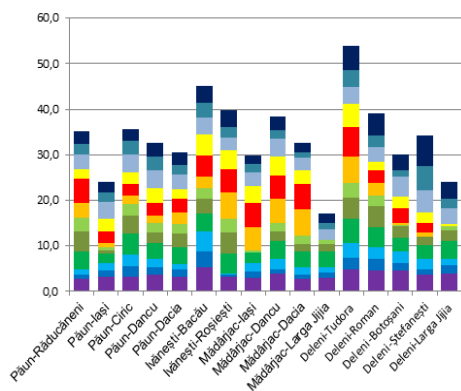


Fig. 15. Thermal inversion phenomena frequency at 07:00 a.m.

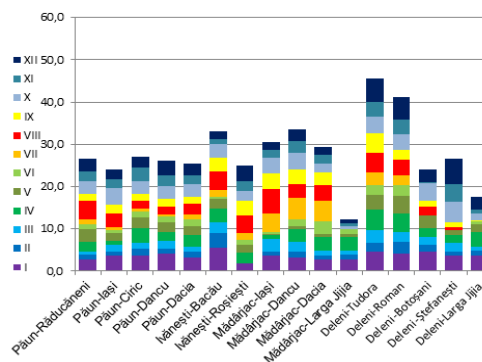


Fig. 16. Thermal inversion phenomena frequency at 08:00 a.m.

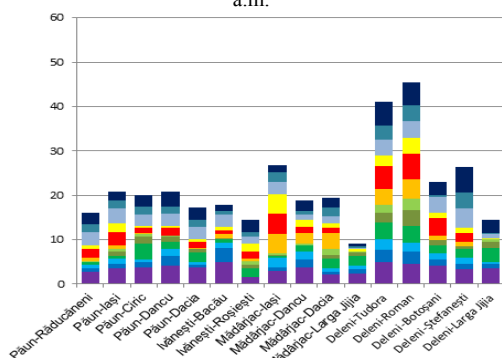


Fig. 17. Thermal inversion phenomena frequency at 09:00 a.m.

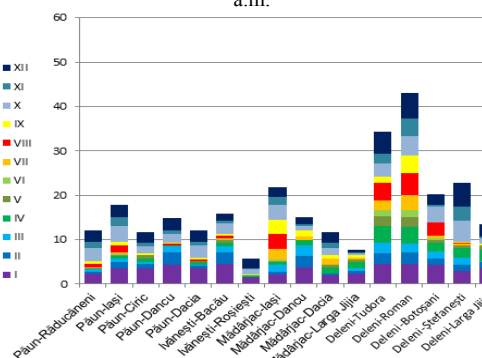


Fig. 18. Thermal inversion phenomena frequency at 10:00 a.m.

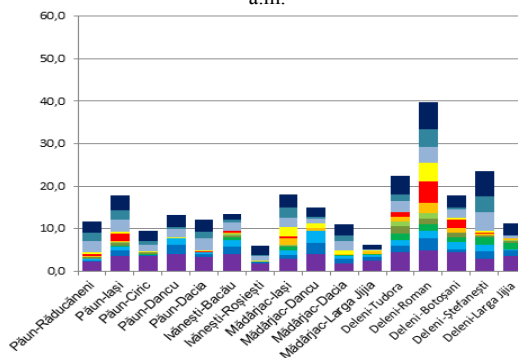


Fig. 19. Thermal inversion phenomena frequency at 11:00 a.m.

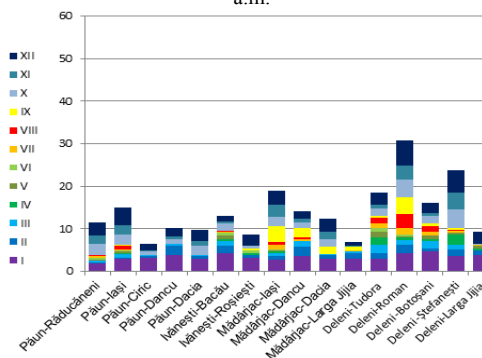


Fig. 20. Thermal inversion phenomena frequency at 12:00 a.m.

2.2.3. Thermal inversion phenomenon frequency in the interval 13:00 – 18:00 p.m. Between 01:00 to 06:00 the thermal inversion phenomenon decrease in frequency for all calculated profiles. Highest frequencies remain those specific to depression and aisle landforms. Throughout the year during this time interval are dominant convective processes that induce normal stratification of vertical air temperature values, generated by the high radiative heat flow.

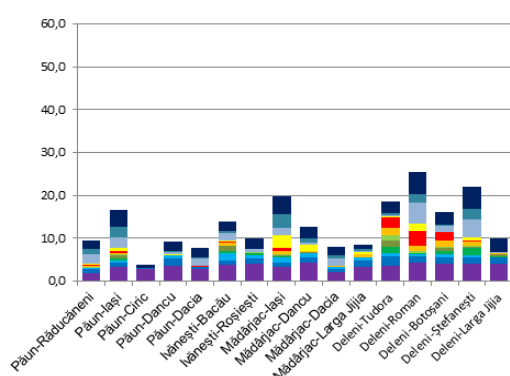


Fig. 21. Thermal inversion phenomena frequency at 13:00 p.m.

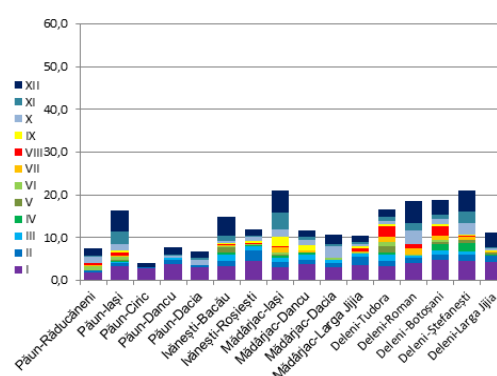


Fig. 22. Thermal inversion phenomena frequency at 14:00 p.m.

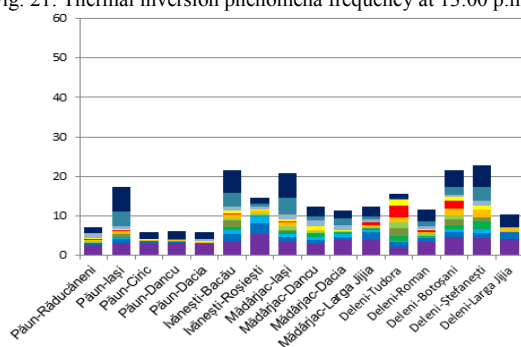


Fig. 23. Thermal inversion phenomena frequency at 15:00 p.m.

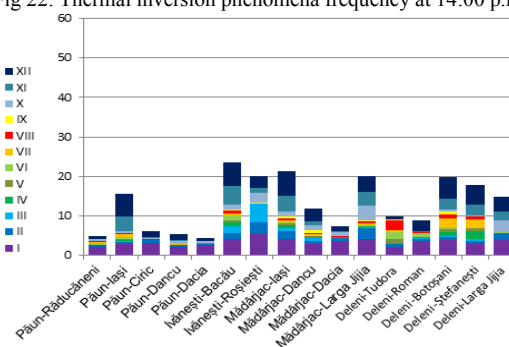


Fig. 24. Thermal inversion phenomena frequency at 16:00 p.m.

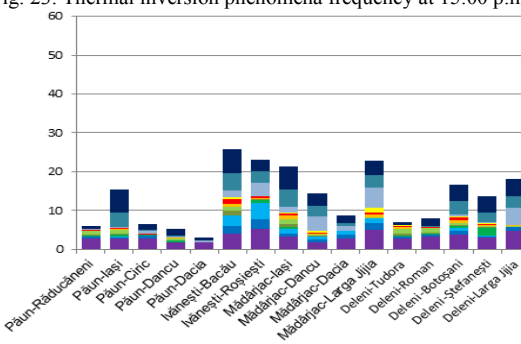


Fig. 25. Thermal inversion phenomena frequency at 17:00 p.m.

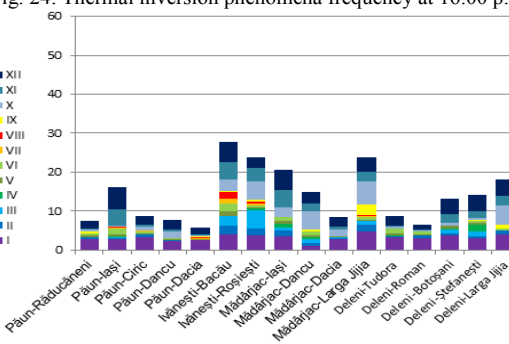


Fig. 26. Thermal inversion phenomena frequency at 18:00 p.m.

Largest frequencies of the thermal inversion phenomenon in this time span represent direct consequences of marked atmospheric stability situations and cloud formation during the cold semester.

2.2.4. Thermal inversion phenomenon frequency in the interval 19:00 p.m. – 00:00 a.m. Along with the decrease in the incidence angle of solar radiation, the intensity of the flux decreases and the caloric radiative heat flow to the end of the day. In atmospheric stability conditions the air descends, gradually cooling as it gets

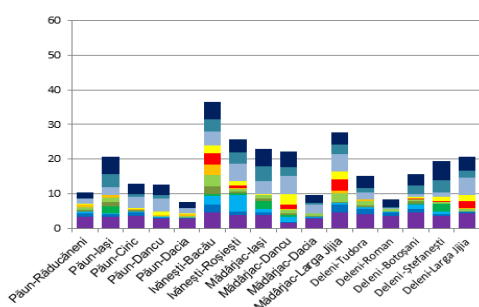


Fig. 27. Thermal inversion phenomena frequency at 19:00 p.m.

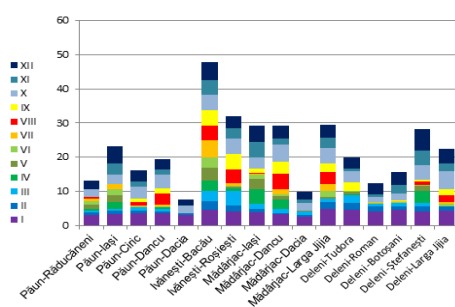


Fig. 28. Thermal inversion phenomena frequency at 20:00 p.m.

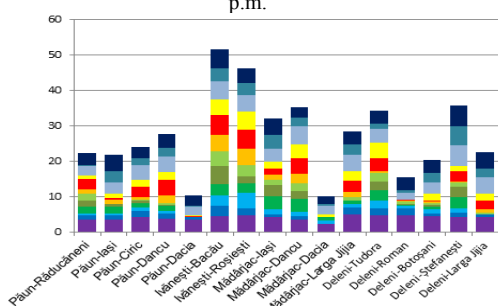


Fig. 29. Thermal inversion phenomena frequency at 21:00 p.m.

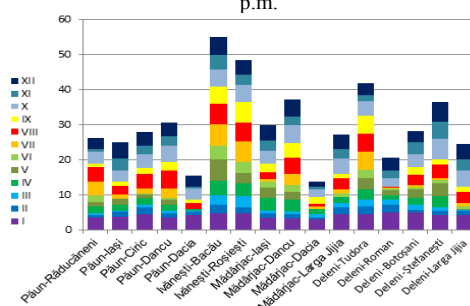


Fig. 30. Thermal inversion phenomena frequency at 22:00 p.m.

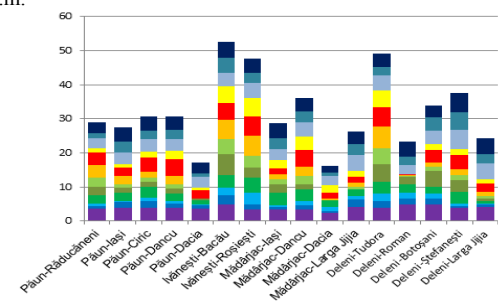


Fig. 31. Thermal inversion phenomena frequency at 23:00 p.m.

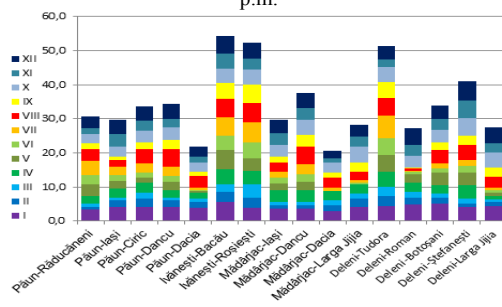


Fig. 32. Thermal inversion phenomena frequency at 00:00 a.m.

lower to the ground. In most cases, compression inversions (sedimentation) increase in frequency towards the second part of the day.

The interval 19:00 – 00:00 is characterized by progressive increase in frequency regarding the thermal inversion phenomenon on all the analyzed profiles. This increase is produced synchronously at all points of observation, approaching specific frequency values specific to 01:00 a.m.

Conclusions

Mild thermal inversions occurred throughout the year with a higher frequency in the cold months of the semester. Still, if they occur during transition seasons they can generate cold waves and frost periods phenomena associated with the occurrence of sudden cooling (rime, glaze, etc).

At regional level it can be distinguished a number of areas where the frequency, duration and intensity of thermal inversion phenomenon manifest itself in different ways. Siret river is highlighted by large frequencies of thermal inversion phenomena that occur throughout the year, reaching the highest frequencies in both monthly and hourly regime.

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