"ALEXANDRU IOAN CUZA" UNIVERSITY
FACULTY OF GEOGRAPHY AND GEOLOGY
DOCTORAL SCHOOL OF CHEMISTRY, EARTH AND LIFE SCIENCES

STUDY OF THERMAL INVERSIONS IN THE AREA BETWEEN THE RIVERS PRUT AND SIRET

Thesis Summary

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Introduction

The thesis is part of the research area with direct references on geography and climate particularity of thermal inversion phenomena that differentiated manifeta the area between the rivers Prut and Siret.

The topic chosen develops a distinctive character on the analysis of the phenomena of thermal inversion phenomena affecting a series of particularities differently climatic and topoclimatic within the region. In this paper we provide a number of important contributions on the manifestation, frequency and intensity of thermal inversion phenomena that induce dysfunction socioeconomic mainframe systems.

The work is divided into 12 chapters:

Keywords: thermal inversions, thermal gradient, atmospheric stability, frequency, MODIS, experimental meteorological observation network.

1. Geographical position

Study area is located in Romania and is between the rivers Siret in the west and south-west to its confluence with the Danube and Prut river, which is the border line between Romania and Moldova in the east.

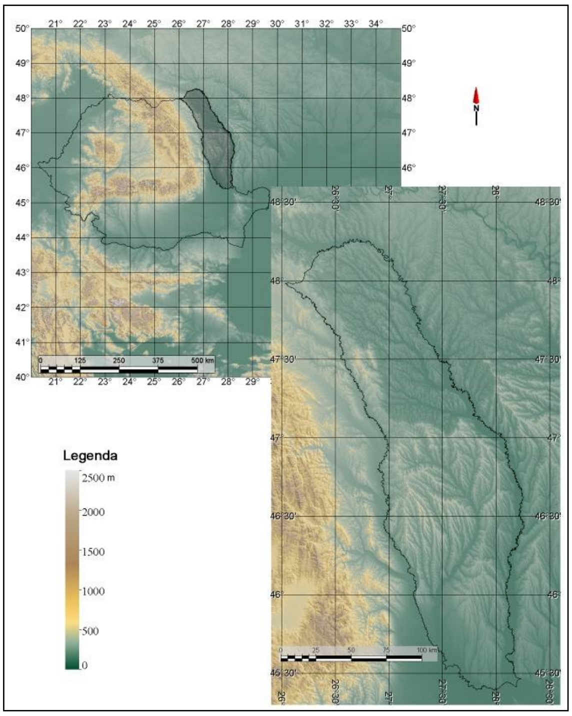
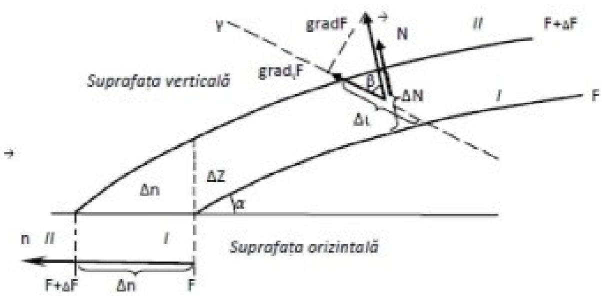


Fig. 1.Locating the study area in Romania

3. Theoretical aspects.

3.1. Thermal gradients

The variation of meteorological elements in time and space (fig.) led during research to the integration of new meteorological terminology. Spatial variation of a meteorological element is called *echiscalar surface* and it represents "areas where the meteorological element retains everywhere the constant value", being specific in meteorology they are called: pressure - isobaric surfaces; temperature - isothermal; density - isostatic; etc. (Matveev, 1958).



Variation in time and space of weather elements (L.T. Matveev, 1958)

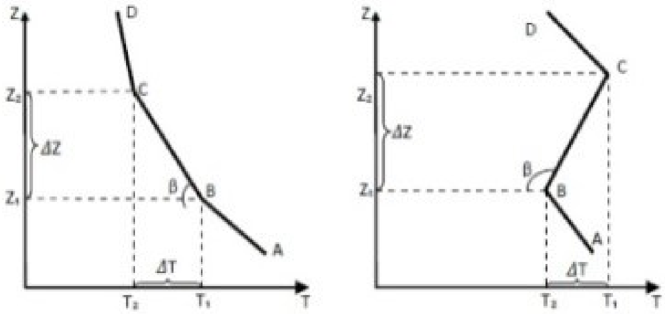
$$|grad\ F| = \lim_{\Delta N \to 0} \left(-\frac{\Delta F}{\Delta N}\right) = -\frac{dF}{dN}$$

If:

γ> 0, the temperature decreases with height that T > T ,

γ = 0, the temperature remains constant so that T = T (isothermal),

γ< 0, the temperature increases with altitude andT < T - thermal inversion.



The curve of temperature distribution in height (state curve) after Matveev 1958; The curve of temperature distribution in height for a situation of thermal inversion (state curve)

In these conditions we can see that:

$\measuredangle\beta < \frac{\pi}{2}$, the temperature of that layer decreases faster and γ is higher,

$\measuredangle\beta = \frac{\pi}{2}$, the stratification of the layer is isothermal and γ is 0,

$\measuredangle\beta > \frac{\pi}{2}$, the stratification of the air is specific for inversions and γ becomes negative indicating air temperature increases with altitude.

3.2. Temperature inversions

The inversion layer does not allow the development of *thermal convection* and *turbulent mixing,* in these conditions denser and cooler air is contoned near the soil surface (Apăvăloae, et. al., 1994, 1996). In these conditions, in the studies developed so far, thermal inversions are characterized depending on the forming and manifestation.

5 Temperature of the air

5.1. The average annual temperature

Multiannual average temperature in region varies between 7,8°C at Suceava and 10,7°C at Galați being characteristic of a thermal difference of about 2,9°C. The value of multiannual average temperature in the area between the rivers Siret and Prut is about 9,2°C.

5.2. The average semestrial temperature

5.2.1. Cold semester

Within the region, multiannual average temperature of cold semester for the analyzed period, ranges from 2,9°C at Galați to 0,9°C at Avrămeni. Thermal difference between the northern and southern is around 2,0°C. Multiannual average temperature of the region is about 1,7°C.

5.2.2. Hot semester

Multiannual average temperature is around 16,5°C and it is characterized by thermal multinnual averange values ranging from 18,1°C in the south of the region (meteorological station Galați) and 15,7°C (meteorological station Darabani) in the north, but in fig. lowest temperatures recorded in high areas in Dealul Mare-Hârlău, characterized by thermal values below 15°C.

5.3. The season average temperature

5.3.1. The average temperature of winter season

In terms of temperature, the winter season is characterized by negative multiannual average temperatures recorded at all weather stations that we have used in the range from 1961 to 1998.

5.3.2. The average temperature of spring season

Spring average temperature varies between 10,5°C within the region weather station Galati and 8,5°C in the north of the region Darabani weather station

In latitude, the specific multiannual average temperature of the area between the rivers Siret and Prut decreases from south to north by a thermal gradient of about 0,7°C/1°lat.

5.3.3. The average temperature of summer season

The multiannual average temperature of summer season in this region is about 19,6°C. The highest air temperature averages were recorded mainly in the south but extremely large expansion along the Văii Prutului. It can be seen (fig.) as 21°C and 20°C isotherms migrate to north. Thus, the 21°C isothermal forwards north to north of Huşi meteorological station and the 20°C isotherm forwards to the right Ştefăneşti weather station.

5.3.4. The average temperature in autumn season

The distribution of values of multiannual average temperature in winter season respects somehow the same pattern ca şi în anotimpul de vară, as in the summer season, but averages a little higher. The multiannual average temperature in this region is about 9,3°C.

7. Thermal gradients (γ)

Gradients represent the distribution of a climate element in time and space. Analysis and determination of thermal gradients within the region was calculated in pairs of two meteorological stations (fig.7.1).

7.1. Data and Method

For this study we used monthly average temperature recorded and calculated for 25 meteorological stations that operate or have operated in the region. The time to analyze the evolution of the vertical temperature gradient is between the years 1967 - 1998 and is based on common strings of meteorological observations made at the 25 meteorological stations in the region.

7.2. The evolution of multiannual thermal gradients (γl)

7.2.1.Vertical thermal gradients on corresponding profiles of weather station Suceava

Although it is not an integral part of the study region, Suceava weather station gives us good coverage in the north of the region (fig. 7.2.). We have chose this station as a central point for four profiles: Suceava Dorohoi, Suceava - Avrămeni, Suceava - Botoșani and Suceava- Răuseni.

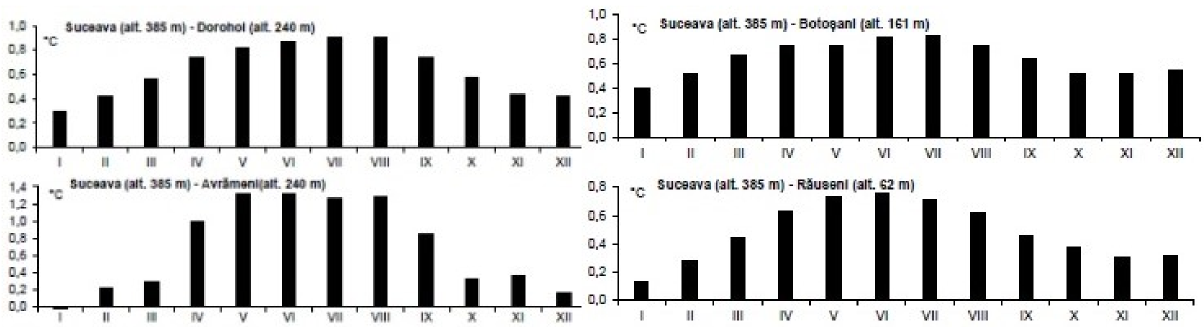


Fig. 9. Thermal gradients monthly multiannual (°C / 100m) in the range from 1967 to 1998: (a) Suceava - Dorohoi; (b) Suceava - Avrămeni; (c) Suceava - Botosani; (d) Suceava - Rauseni.

Suceava - Botoșani profile is individualized by a level difference of about 224 m between the two meteorological stations. The value (γa) is 0,6°C/100 m, showing the same trend as in the profile Suceava – Dorohoi. The regime of the annual thermal gradients has positive values. The spread (γl) during the year is about 0,2°C/100 m.

7.2.2. Vertical thermal gradients on corresponding profiles of weather station Fălticeni.

Fălticeni - Roman profile runs on NV - SV direction the Podișul Fălticenilor, having altitudinal amplitude of about 200 m, and the difference in level between the two meteorological stations about 108 m. The value of (γa) is about 0,4°C/100 m, under the thermal inversion phenomena installation which induces a negative thermal gradients in the profile during winter season.

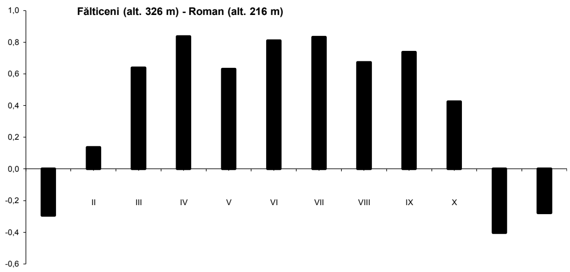


Fig. 10. Monthly multiannual thermal gradients (°C / 100m) between 1967 to 1998, the Roman Fălticeni profile.

7.2.3. Vertical thermal gradients on corresponding profiles of weather station Cotnari.

Cotnari - Roman profile corresponds to a relative altitude between meteorological stations of about 71 m, is characterized by a negative value (γa) about -0,8 °C/100 m. The regime of monthly average thermal gradients is kept negative throughout the year, except April.

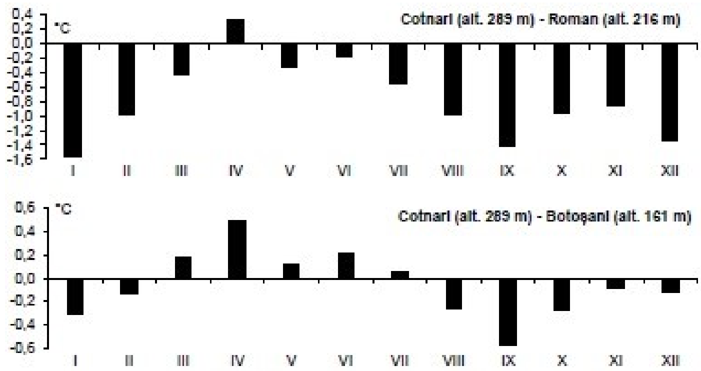


Fig. 11. Monthly multiannual thermal gradients (°C / 100m) between 1967 to 1998: (a) Cotnari - Roman; (b) Cotnari – Botosani

7.3. The evolution of vertical thermal gradients within the network of experimental observations in 2013

The network in which experimental observations were carried out on air temperature records at intervals of an hour and it covers well the existing gaps of the national network of meteorological observation.

7.3.3. Vertical thermal gradients on corresponding profiles of experimental observation point Deleni.

Deleni – Tudora profile with a relative altitude of about 231 m, has null characteristic vertical thermal gradient in 2013. Stand on an annual basis of low vertical thermal gradient, intensity values are influenced by large inversion phenomena what are the specific heat throughout the year.

Deleni – Roman profile, although it is part of Siret Corridor on an annual regim, can be seen a number of major differences compared to the other profiles to observations points aisle. Average thermal gradient in 2013 was about 0,4°C/100.

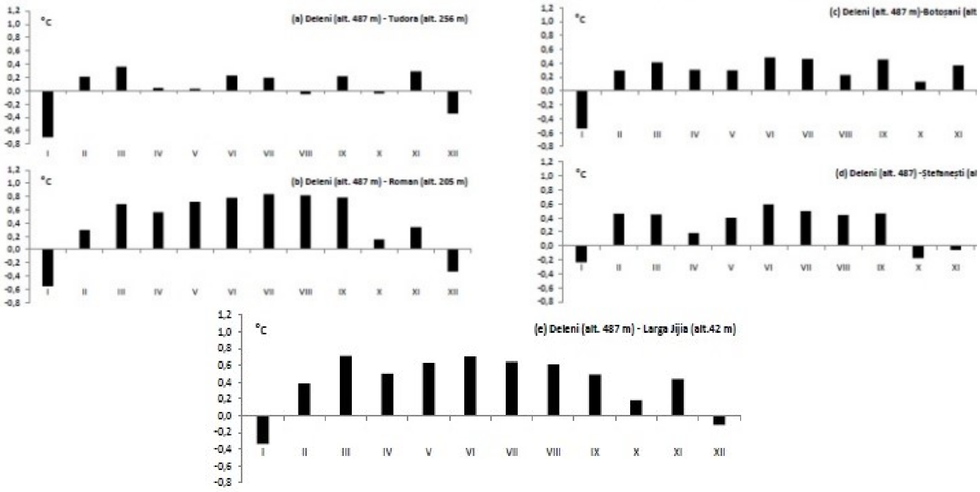


Fig. 12. Monthly average thermal gradients (°C / 100m): (a) Deleni - Tudor, (b) Deleni - Roman, (c) Deleni - Botosani, (d) Deleni - Ştefăneşti, (e) Deleni - Larga Jijia in 2013

8. The frequency thermal inversion phenomena

8.1. Data and Method

We used hourly data obtained in observational network with a number of common observations during 2013. Frequency thermal inversion phenomena was calculated for each profile, as in the analysis of vertical temperature gradient.

8.2. Annual frequency of thermal inversion phenomena

Using monthly data we can not determine the frequency of thermal inversion phenomena, especially relative radiation occurring in the first part of the day, they are produced on short time durations being easily dissipated after sunrise.

8.3. Monthly frequency of thermal inversion phenomena

In the Romanian literature there are no papers that are analyzed the inversion phenomena at times over a period of about 1 year. In most of the papers of Romanian literature in which reference is made on thermal inversion phenomena, they are associated in most cases with specific periods of abrupt cooling of the cold semester. On an annual basis are a number of references on thermal inversion phenomena especially in mountainous area.

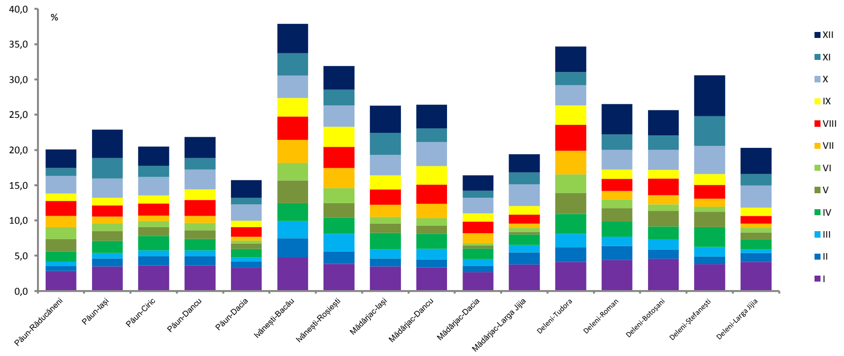


Fig. 13. Monthly frequency thermal inversion phenomena 2013

8.4. Hourly frequency thermal inversion phenomena

8.4.1. Frequency thermal inversion phenomena in the time slot 1:00 to 6:00

Radiative inversion which are manifested amid nocturnal radiative cooling specific intervals, induce an increase in frequency after midnight continue to grow in frequency throughout the night until the early hours. Maximum frequency of manifestation of thermal inversions occur predominantly at around 5:00. Time for producing thermal inversions maximum frequency depends on the time when the sun rises, is limited by atmospheric dynamics and local features of the landscape, the frequency gradually ranging from one month to another.

8.4.2. Frequency thermal inversion phenomena in the time slot 7:00 to 12:00

With the sunrise, the frequency of thermal inversion phenomena gradually decreases. You can see a major differences from one hour to another. The largest differences are observed in the warm semester, where the the increasing of the intensity of radiative heat flow, thermal inversions start easily be dissipated by heat flow induced upward growth.

8.4.3. he frequency thermal inversion phenomena in the time slot 1:00 p.m. to 7:00 p.m.

The time slot between 19:00 - 00:00 is characterized by progressively increasing frequency of thermal inversions on all profiles analyzed. Increased occurs almost synchronously at all points of observation, approaching the 1:00 o'clock, the specific frequency values.

8.4.4. Frequency thermal inversion phenomena in the time slot 7:00 p.m. to 0:00

The time slot between 19:00 - 00:00 is characterized by progressively increasing frequency of thermal inversions on all profiles analyzed. Increased occurs almost synchronously at all points of observation, approaching the 1:00 o'clock, the specific frequency values.

9. The intensity of thermal inversion phenomena

The intensity of the thermal inversion phenomenon is a consequence of several factors that are determinants to identify the degree of intensity of the duration of an episode of inversion, the manifestation, severity and not the least deviation from the average range.

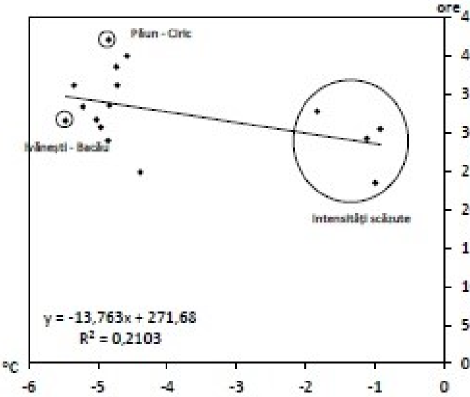


Fig.9.1. Duration and intensity of thermal inversions in January 2013

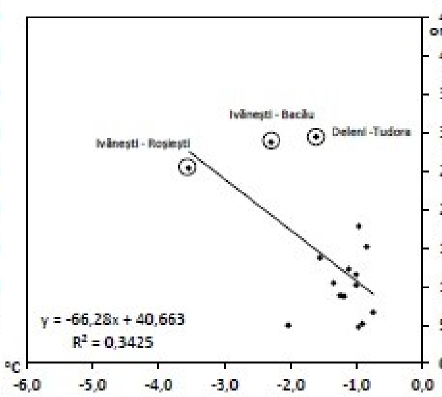


Fig.9.2. Duration and intensity of thermal inversions in July 2013

The specific warm months of the semester are characterized by low frequency thermal inversion phenomena, but when this phenomenon occurs in some cases can cause major malfunctions. The intensity of thermal inversions in the warm half of the year, is high only when the phenomenon generates negative temperatures. For the month of July 2013, we can not talk about the severity of thermal inversion phenomena, whereas it showed no negative temperatures at any time of observation. However, during thermal inversions becomes a risk factor inducing a number of issues on the health of the population by blocking and blocking imdediata pollutants in the vicinity of the earth's surface.

In the literature, the intensities of thermal inversion phenomena are sorted by the thermal differences between weather stations located at different altitudes (Bogdan, 1999). The following classification was developed:

- weak inversion, <0.1 - 3,0°C
- inversions average intensity 3.1 - 5,0°C
- inversions with high intensity from 5.1 to 10.0 °C
- High intensity inversions> 10.1 °C

To calculate the intensity of thermal inversion phenomena, taking into account the parameters that directly influence the intensity of thermal inversion phenomena, we must take into account all the factors that generate and amplify its effect. Accordingly, we propose the following formula:

$$\boldsymbol{I} = \left(\frac{\Delta \boldsymbol{t_1} * \boldsymbol{h}}{\Delta \boldsymbol{t_m} - \Delta \boldsymbol{t_1}}\right) / \mathbf{10}$$

were:

$\boldsymbol{I}$ – intensity episode thermal inversion in degrees of intensity;

Δt_1 – the average temperature difference between two points in a range of inversion;

h – hours specific amount of a thermal inversion interval;

Δt_m – minimum temperature difference specifies a range of thermal inversion.

It is considered that the number of hours an episode characteristic thermal inversion is liable utmost intensity of the phenomenon (Donald, 1969). The air temperature can fall to very low values, as long as the duration of the phenomenon is greater, inducing a higher degree of severity.

Applying the above formula, we identified specific intensity all ranges of specific thermal inversion in the studied area of 2013.

The degree of intensity obtained for a period characterized by thermal inversion phenomena vary if the temperature values recorded during 2013 between 0.1 and 26.6 degrees of intensity.

The degree of intensity of thermal inversion phenomena:
Very low intensity ≤2,5
Low intensity from 2.5 to 5
Moderate 5-10
High intensity 10-15
High intensity 15-20
Extreme intensity ≥20

Periods of thermal inversion intensity expresses very well the impact of genetic factors on the periods in which these phenomena occur and cause their production. In the year 2013 we see a very large number of thermal inversion phenomena with lower degrees of intensity 2,5.

Tab. 14. The intensity of thermal inversion episodes intensity classes in 2013

Profile	**≤ 2,5**	**2,5 – 5**	**5 – 10**	**10 – 15**	**15 – 20**	**≥20**	**Total**
Păun-Răducăneni	142	38	9	1	1	0	191
Păun-Iași	148	31	9	***3***	0	0	191
Păun-Ciric	123	42	9	2	1	0	177
Păun-Dancu	136	41	10	2	1	0	190
Păun-Dacia	101	29	8	2	1	0	141
Ivănești-Bacău	178	***118***	15	***3***	1	0	***315***
Ivănești-Roșiești	182	87	16	***3***	1	0	**289**
Mădârjac-Iași	205	34	6	1	1	0	247
Mădârjac-Dancu	***214***	43	8	0	1	0	266
Mădârjac-Dacia	171	17	4	1	0	0	193
Mădârjac-Larga Jijia	149	35	6	1	0	0	191
Deleni-Tudora	168	111	8	1	0	0	**288**
Deleni-Roman	168	51	6	1	***3***	0	229
Deleni-Botoșani	177	33	8	1	***3***	1	223
Deleni-Ștefanești	151	58	***17***	1	1	1	229
Deleni-Larga Jijia	115	35	10	1	2	1	164
Total	**2528**	**803**	**149**	**24**	**17**	**3**	**3524**

In the year 2013 there were about 803 cases of mild thermal inversions on all 16 profiles analyzed. At the annual level, it can be seen (tab.14) a strong increase in thermal inversion phenomena with low intensity in Siret, where their number is two times higher than in other regions (Ivanesti - Deleni 118 cases and Deleni - Tudora 111 cases).

Increased atmospheric stability, specific January, lead to thermal inversions and training with high intensity, which are recorded in the year 2013 only in January and December.

Tab. 15. The intensity of thermal inversion episodes intensity classes within January-October 2014

Profile	**≤ 2,5**	**2,5 – 5**	**5 – 10**	**10 – 15**	**15 – 20**	**≥20**	Total
Păun-Răducăneni	158	78	13	1	0	0	250
Păun-Ciric	164	55	3	1	1	0	224
Păun-Dancu	157	69	4	2	0	0	232
Păun-Dacia	146	37	5	0	0	0	188
Ivănești-Roșiești	161	88	***22***	1	0	0	***272***
Mădârjac-Dancu	***214***	48	11	1	0	0	274
Mădârjac-Dacia	152	25	1	0	0	0	178
Mădârjac-Larga Jijia	169	32	4	0	0	0	205
Deleni-Tudora	110	***118***	19	1	2	1	251
Deleni-Roman	127	61	7	1	0	1	197
Deleni-Ștefanești	104	61	9	***11***	***3***	***5***	193
Deleni-Larga Jijia	127	45	8	0	1	1	182
Total	**1789**	**717**	**106**	**19**	**7**	**8**	**2646**

Thermal inversion phenomena that reach very high intensities are characteristic of particular winter months. The high degree of severity, length of time and hence high intensity is a consequence of several genetic factors of this type of phenomenon.

6. Thermal anomalies, results of thermal inversion phenomena

Most times, the distribution and the regime of air temperature do not keep the normal trend unifying values. However, where the climate genetic factors influence disproportionately the regium and the distribution of climatic elements.

6.1. The distributun of multiannual average temperature of characteristic months (January and July)

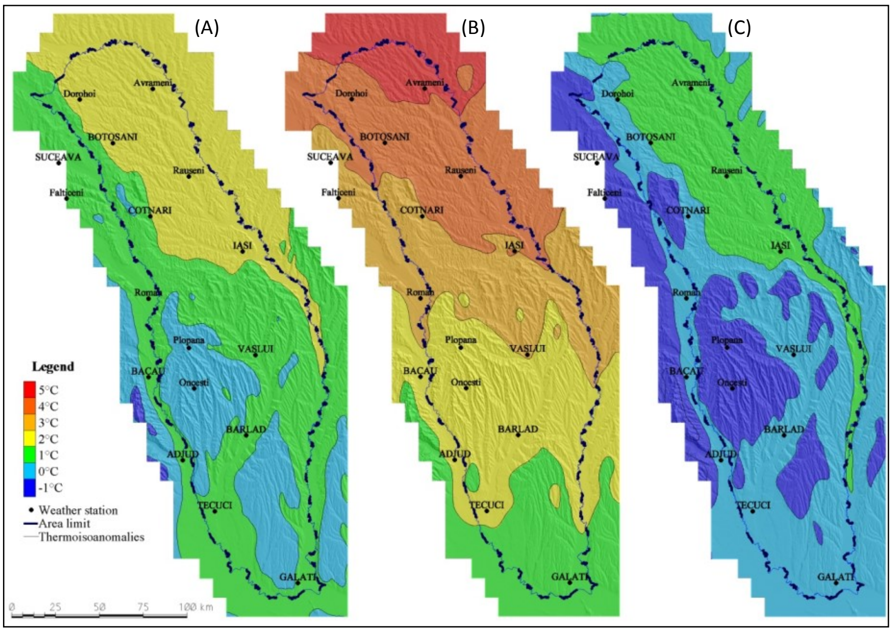
In the area between the rivers Siret and Prut multiannual average temperature descends in the range between 7°C in high area of Dealului Mare-Hârlău and maximum values of 11°C in low areas of southen part of the region. In the north half of Câmpiei Colinare a Jijiei and the high areas of Podișului Central Moldovenesc the thermal values range between 8-9°C.

6.2. The distribution of average annual temperatures at sea level.

Using specific vertical thermal gradients: 0,51°C/100 m for multiannual average temperature, 0,3°C/100 m for January and 0,7°C/100 m for July there were made distribution models of termoizanomale (Apostol, 1990). Within the region there is a more homogenous distribution of the average temperature factor of altitude. In these conditions, can be seen very well the induced abnormalities, by latitudinal and morphological variation and the surface characteristics of active and influence the region.

6.3. The distribution of annual average of termoizanomals and of characteristic months.

Based on values of air temperature on sea level, average thermal values were calculated using the specific horizontal latitudinal thermal gradients between 40-50 ° N latitude. If in the distribution mode of average temperatures reduced to sea level the latitudinal factor actively influence the air temperature, in case of thermal anomalies reduced at sea level and on the same latitude. It highlights the better features of several other factors that influence actively the average air temperature distribution in the area between the rivers Siret and Prut.



Average Termoizanomals reduced at sea level: annual (A); January (B); July (C).

Horizontal thermal gradient of January is about 1,23°C/1°latitudine (Apostol, 1990). The abnormalities with the highest values above 5 ° C is recorded particularly in the far north of the region. Carpathian arc and the active influence of Atlantic air masses make their mark on the way of the distribution of average termoizanomalelor of January, their values decreased to values below 1 ° C for the southern third of the area.

12. The impact of thermal inversion phenomena on human society

In addition to the data obtained and analyzed from the two networks observations have been used a number of spatial modeling on the active surface temperature Siret corridor

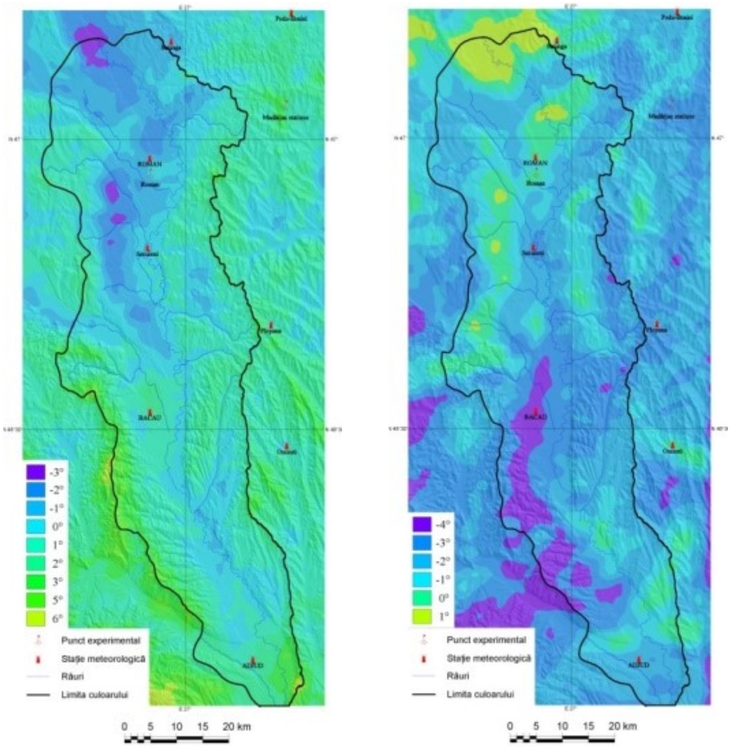


Fig. 19. The distribution of air temperature recorded MODIS satellite platforms for intervals marked by thermal inversions in 2012 at 11 UTC (left), 22 UTC (right).

Although in recent years the industry has significantly reduced emissions, air pollution problem remains extremely important. For example, during the winter and spring seasons, smoke vents active throughout the region that takes place between the Prut and Siret river valleys, emit large amounts of carbon monoxide resulting from the combustion plant mass. This is basically a "ritual" specific to each household in rural areas, sometimes in suburban environment. In this category, we add stubble fires.

Conclusions

Thermal inversion phenomena are closely related to morphometry and morphology of depression areas, these being the defining factors in the occurrence, intensity and frequency thermal inversion phenomena.

Data provided by MODIS LST module can be successfully used in studying the intensity, distribution and distribution areas of thermal inversion phenomena, even if the thermal values are much higher than those obtained in points of observations. TWI module can be used in studies of urban topoclimatologie, Agrometeorology etc.

Thermal inversions occur throughout the year differentiated according to the duration of sunshine, the radiative heat flow and its balance, morphometry and morphology of the region, atmospheric dynamics and seasonal peculiarities of the ground.

Vertical thermal gradients calculated on the basis of average monthly temperatures well play areas where thermal inversion phenomena occur with a high frequency during the year.

In this region, there are a number of areas where the frequency, duration and intensity of the thermal inversion phenomenon is manifested in different ways. Siret corridor is distinguished by high frequency thermal inversion phenomena that occur throughout the year, reaching the highest frequencies, both under monthly, daily and hourly.

The intensity of thermal inversion phenomena are a consequence of the duration, severity and thermal regime generated from a thermal inversion episode.

Thermal radiation inversions are characterized by low intensity and probability of occurrence throughout the year and especially in the first part of the morning.

Thermal inversion phenomena at low levels are particularly high frecveţa in December, is characterized by a high share of 48% in 2013. The average intensity of thermal inversions occur throughout the year, with a higher frequency in the months semester cold. If you encounter transition seasons, can generate waves of cold and freezing periods, with the emergence of phenomena associated with sudden cooling (frost, ice, etc.).

Thermal inversion phenomena high intensity and extremely specific winter season, it is possible over long periods of time and often generate the air temperatures very low. Baric formations are generated by continental anticyclones home extremely cold, especially cold period specific.

Thermal inversions generates dysfunction natural systems, socio-economic, climatic risk associated phenomena causing low temperatures induce major dysfunction of natural systems, cause major losses in agriculture.

The high degree of stability in heavily polluted urban centers, industrial areas or in rural areas, these phenomena are directly responsible for increasing levels of pollutants, noxious and particulate matter in the lower atmospheric layers.

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