Lucrările Seminarului Geografic Dimitrie Cantemir
Vol. 40, October 2015, pp. 47-56
http://dx.doi.org/10.15551/lsgdc.v40i0.05

Air temperature anomalies between the rivers Siret and Prut in Romania

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To cite this article: Ichim, P.,Apostol,L., Sfîcă, L., Kadhim-Abid, A.L. (2015). Air temperature anomalies between the rivers Siret and Prut in Romania. *Lucrările Seminarului Geografic Dimitrie Cantemir*, Vol. 40, pp. 47-56. DOI: 10.15551/lsgdc.v40i0.05

To link to this article: http://dx.doi.org/10.15551/lsgdc.v40i0.05

ISSN: 1222-989X www.seminarcantemir.uaic.ro

LUCRĂRILE SEMINARULUI GEOGRAFIC “DIMITRIE CANTEMIR” NR. 40, 2015

AIR TEMPERATURE ANOMALIES BETWEEN THE RIVERS SIRET AND PRUT IN ROMANIA

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Abstract. The morphological and morphometric relief features, diversity of the active surfaces influencing air temperature distribution, especially the active influence of the Black Sea, position towards the Carpathian Orogen and large latitudinal extension of the studied aria, represent elements that compel towards a detailed study upon how air temperature is distributed and about the positive or negative thermal anomalies within the area under study. Therefore in order to determine thermal anomalies, 19 meteorological stations were used, stations running both within the area under study but also in its proximity. For the determination of air temperature anomalies, vertical thermal gradient for the whole Moldova region was computed and used, sequently the mean annual, of the January and July month air temperature was lowered according to sea level. Then, we used the horizontal thermal gradient range specific of the interval between 40°-50° North latitude of the continental area, to bring to a common latitude, for evidence the thermal anomalies. They are produced by local factors of the active surface, especially by the general routes of the general circulation of the atmosphere in this area, trails that are influenced by the major relief of the studied area and from greater distances and by the major baric activity centers. In the south of the studied area was revealed the role of wetlands and of the Black Sea. The results were mapped using, the residual kriging method.

Keywords: air temperature anomalies, kriging, thermal gradient, G.I.S, termoisanomal.

Introduction

Latitudinal difference of approximately 3°, morphological and morphometric features of the relief, active surface, geographical location within the region, alongside the main types of atmospheric circulation represent factors that induce a series of air temperature anomalies. In order to highlight average thermal anomalies of air and characteristic months of January and July, the registered air temperature values were converted at sea level, preserving the latitude by using vertical and horizontal thermal gradients. Lines delineating areas with the same values of specific heat anomalies are named temperature isanomal or termoisanomal his concept being introduced by the german climatologist K. Dove in 1852 (Apostol, 1990).

The area under study is located in Romania, between the rivers Siret in the west and south-west to its confluence with the Danube, and on the east by the river Prut, which is also the state border between Romania and Republic of Moldova. The southern border is marked by the Danube river and its confluence with Siret and Prut rivers. In the north, the limit is set by the state border between Romania and Ukraine.

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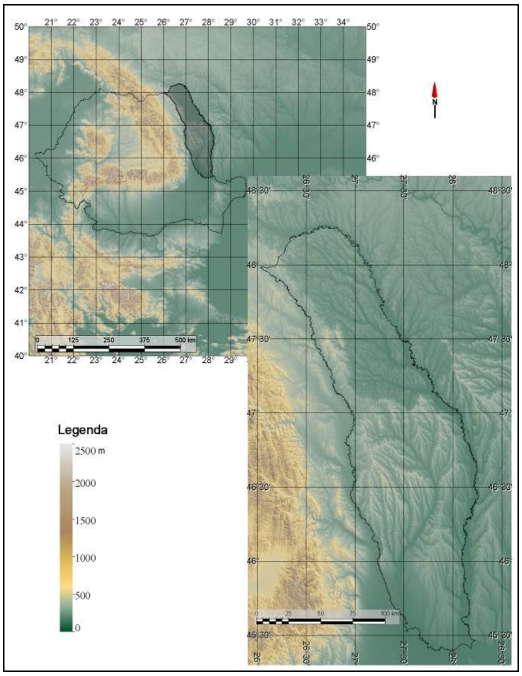

Figure 1: Location of the studied area

The studied area extends approximately 3° latitude and about 2° longitude, which gives a diverse latitudinal climatic conditions. The landscape is characterized by heights ranging from less than 10 m (Lower Siret Plain and the confluence of Danube and Prut rivers) and 593 m in Hârlău-Dealul Mare region (Tudora peak). From the morphometric point of view, on the studied surface area, the representative class is to be distinguished between 100-200 m altitude with a share of about 42.2% (Figure 2) being specific to the south part of the territory and along water courses. Lowest share belongs to altitudinal classes exceeding 400 m which have a small extent in Hârlău-Dealul Mare region and Doroșan hill from Tutova Hills.

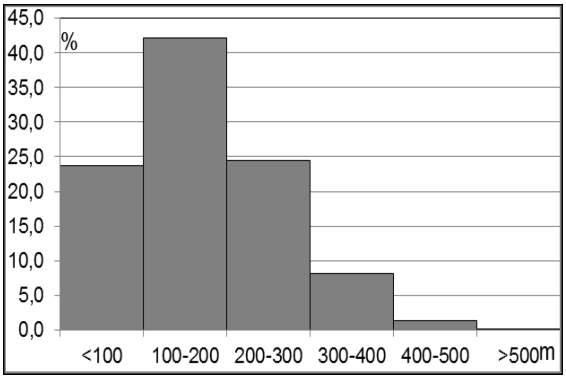

Figure 2: The distribution of frequency altitude classes
in the region between Siret and Prut rivers

Making of this work was based on data from 19 meteorological stations that are part of the observation network N.M.A. (National Meteorological Administration) that have worked or still work in the region. Regarding the altitudinal distribution, the official meteorological network covers well altitudinal classes ranging between 100-200 m and 200-300 m (Table. 1). For intervals with altitudes higher than 300 m, the above mentioned range is very low and covered by two meteorological stations (Fălticeni and Suceava), located outside the studied area but considered crucial in this study.

Table 1: Frequency of the altitude classes and the number of meteorological stations

Altitudinal intervals (m)	Freqvency (%)	Weather stations
<100	23, 7	5
100-200	42,2	6
200-300	24,5	6
300-400	8,2	2
400-500	1,3	0
>500	0,1	0

Materials and Methods

For temperature anomalies analysis, multiannual monthly avereged temperature values were used. These values were recorded and calculated for the 19 meteorological stations that have worked from 1967 until 1998 or still in use today. This period is considered representative due to the number of meteorological stations at which observations were conducted during this interval and it is higher compared to those that continued to carry out observation after 1998.

Based on data from meteorological stations, distribution maps of mean air temperature values for the characteristic months (January and July) and distribution maps of multiannual average temperature using residual kriging method.

Monthly and annual average temperature were reduced to sea level using vertical thermal gradients calculated for Romania. Values of average temperature at sea level were calculated based on the average vertical thermal gradient of 0.5°C, commonly used in Romanian literature (Bâzâc, 1983, Apostol 1990). The values of the average temperature at sea level for characteristic months of January and July were computed based on the vertical thermal gradients, previously calculated by L. Apostol, 1990, using a parabolic equation and values of 0.3°C for January and respectively 0.7°C for July.

The great latitudinal extent of the area in question, approximately 3°C, induces pronounced differences in the distribution of annual average temperatures and characteristic months. Therefore, depending on the horizontal thermic gradients, specific for a latitude range of 40°-50°, the average horizontal thermic gradients for the characteristic months are as follows: 1.23°C for January, 0.58°C for July and the horizontal thermal gradient for the annual average is 0.86°C (Apostol, 1990).

Concerning the spatial modeling methods of air temperature, the most used methods are: regression and kriging method, alongside a series of different versions that can be used for this type of air temperature spatial modeling.

Multiple regression method. This method requires the correlation between meteorological station altitude and the registered thermal value. Once this correlation is achieved one can use the regression formula (Fig. 3) in a GIS software.

Although regression method renders well the altitudinal variation of the air temperature, it lacks highlighting any thermal anomalies (Patriche, 2009), specific to different active surfaces, altitude factors, morphologic and local factors, large latitudinal extents of the region and of active influences of the main barometric centers.

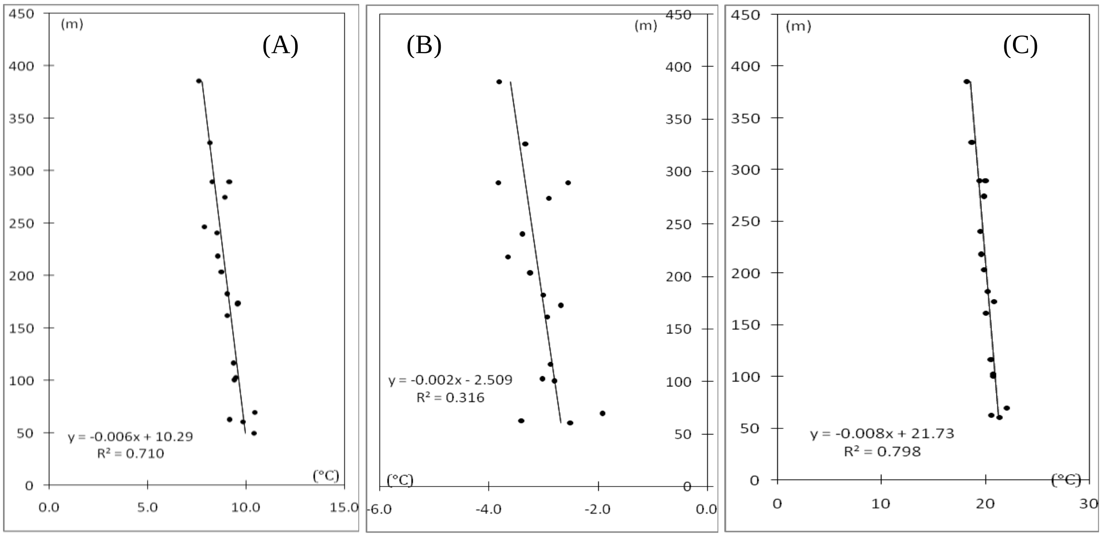

Figure 3: Altitudinal variations of annual average temperatures (A), January (B), July (C)

Kriging method. This method is not conditioned by the altitude factor, parameter considered to be essential in the distribution, occurrence and variation of thermal anomalies within the area. Thus, the study considers this method to be suitable in mapping low and reduced at sea level thermal variations based on specific vertical thermal gradients. Morphometric parameters influence stands out only when a certain point registers temperatures higher than those registered in neighboring points located at lower altitudes, thus indicating local variations of air temperature. Kriging method is more suitable because it highlights better latitudinal and longitudinal variations of air temperature but in terms of altitudinal homogeneity and unfragmented or slightly fragmented.

Although both methods (multiple regression and kriging method) can be applied, the results would be only half true for each modeling. Hence, residual kriging method is indicated because it is the best correlation between the two residual categories (Patriche, 2009).

Residual kriging method uses both of the above mentioned methods. This method implies applying multiple regression and then interpolating the residues of the regression by ordinary kriging. The results are added up, thus obtaining the final spatialization known as residual kriging or kriging trend model, regression - kriging as the optimal method of climatic parameters spatialization (Patriche, 2009). Based on this method, maps depicting the distribution of average temperature within the area were realised.

The spatial distribution of air temperature values at seal level involved a complex analysis in which the altitudinal factor was considered essential. Based on the distribution of temperature values registered and calculated for each station, and on the ground numerical model, simplified by a 250 m resolution and derived from the SRTM (Shuttle Radar Topography Mission), vertical thermal gradients at sea level was calculated for each pixel.

With the model for air temperature distribution at sea level and GIS techniques, the team was able to calculate thermal values for air, converted at sea level and on the same altitude. This is how mathematical models of the anomalies of annual average temperatures and of the characteristic months of January and July were obtained. This phase was achieved through lowering annual average temperatures from the obtained model by applying vertical and horizontal thermal gradients within the region.

Results and discussion

Distribution of annual average temperatures and characteristic months

In the area between the rivers Siret and Prut, the annual average temperature falls in the range between 7°C for Hârlău -Dealul Mare area and maximum values of 11°C in the low areas of the southern region. In the northern half of Jijia Plain Hill and the higher areas of Central Moldavian Plateau, thermal values range between 8-9°C. Thermal values greater than 9°C were registered in low areas, in the central-southern sector of Jijia Plain Hill, in Bacău-Adjud sector within the corridor of Siret river (Figure.4-A). Highest average temperatures are characteristic for the southern region. The altitudinal, morphological and latitudinal factors corroborated with the position towards the Carpathian ridge and distance from the Black Sea dictate the distribution pattern of air temperature values throughout the year.

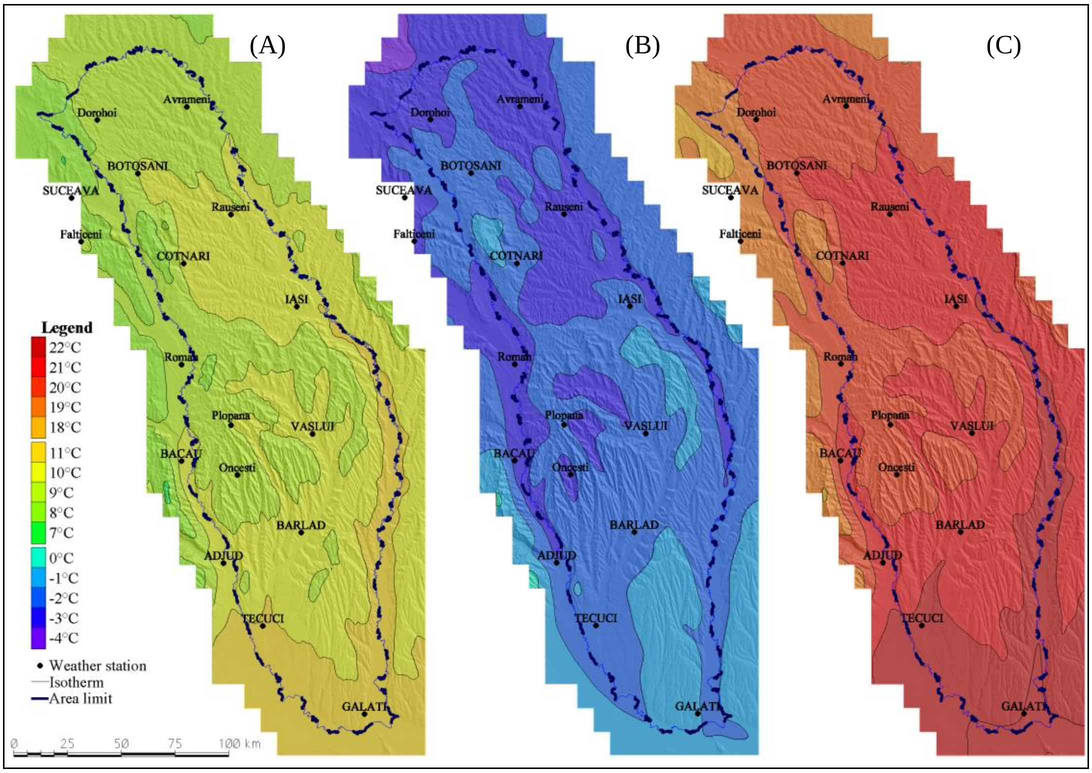

Figure 4: Temperature distribution: average multiannual (A); January average multiannual (B); July average multiannual (C).

The month of January is characterized by negative multiannual average temperatures (Figure 4-B). Distribution of the annual average temperature for January is specific to lower aisle region and micro depression. Altitude puts his mark on the distribution pattern of average temperatures for January, the typical average annual temperatures reaching -3°C for Siret couloir in Paşcani- Adjud district, Negreşti depression and the northern district of Tutova Valley. This mode of distribution of mean air temperatures in the lowlands and aisles is a consequence of thermal inversion phenomena, specific to periods of enhanced stability under the influence of the maximum pressure center generated by the Siberian anticyclone and accelerated expansion towards the south of the Scandinavian anticyclone.

Cold air masses driven from northeast present a maximum thicknesses of 500-600 m, often present in the area (Apostol, 2004, Sfîcă, 2009). Even after the withdrawal of the maximum pressure center, depression areas are invaded by cold air settles on the bottom of the valley corridors and depressions, increasing thermal inversion phenomena (Apostol, 1990).

At multiannual level, July (Figure. 4-C), is characterized by thermal values ranging from 19°C in Hârlău- Dealul Mare and in low areas of the southern region, the average thermal values are found between 21 and 22°C. It can be seen an approximately identical as the distribution specific for multiannual averages. Continental influences are manifesting mainly in the lower regions, the valleys of Prut and Siret rivers, generating high average temperatures and high thermal amplitudes, characteristic to the months of January and July. The morphology of the valleys and flow paths on the north favors advection of warm air from the south of the continent, but also the degree of continentalism that marks the temperature values for July.

Distribution of average annual temperatures at sea level

Using specific vertical thermal gradients: 0.51°C/100 m for multiannual average temperatures, 0.3°C/100 m for January and 0.7°C/100 m for July, distribution models for termoisanomal were created (Apostol, 1990). Within the region there is a more homogenous distribution of the average temperature on the background of cancellation of the altitudinal factor. Given this conditions, it can be observed very well the anomalies induced by the altitudinal and morphological variations and the characteristics of the active surfaces that influence the region.

The distribution of the multiannual average temperatures reduced at sea level vary between 10°C in the north and the insular high areas of the frames from the Moldavian Central Plateau, following the normal trend of multiannual average temperature distribution within the region, except Hârlău- Dealul Mare and especially on the eastern slope. This type of thermal anomaly can be atributted to the intensification of foehn winds, specific to eastern slopes (Figure 5-A).

The great extent of the maximum Siberian pressure center and altitudes, mostly low with a frequency of approximately 90% of altitude classes below 300 m are most exposed to cold air advection. This situation induces negative average thermal values below -3°C in a considerable part of the region, highlighting the high frequency thermal inversion phenomena. As it can be observed in Figure 5-B, high areas of the region are characterized by temperatures 2-3°C higher than in the lowlands. This type of distribution of average temperatures in January is a consequence of advection of cold air from the north-eastern part of the continent, of periods characterized by enhanced atmospheric stability specific to the Siberian anticyclone, of active surfaces characteristics and of negative caloric balance, specific to this month.

Low thermal anomalies at sea level in July (Figure 5-C) are more faded, specific average temperature varies from 22°C in the south and 20°C in the north. This distribution of values reduced at sea level, specific for the month of July, depict the pronounced influence of the latitudinal factor in the distribution pattern of average temperatures reduced to sea level.

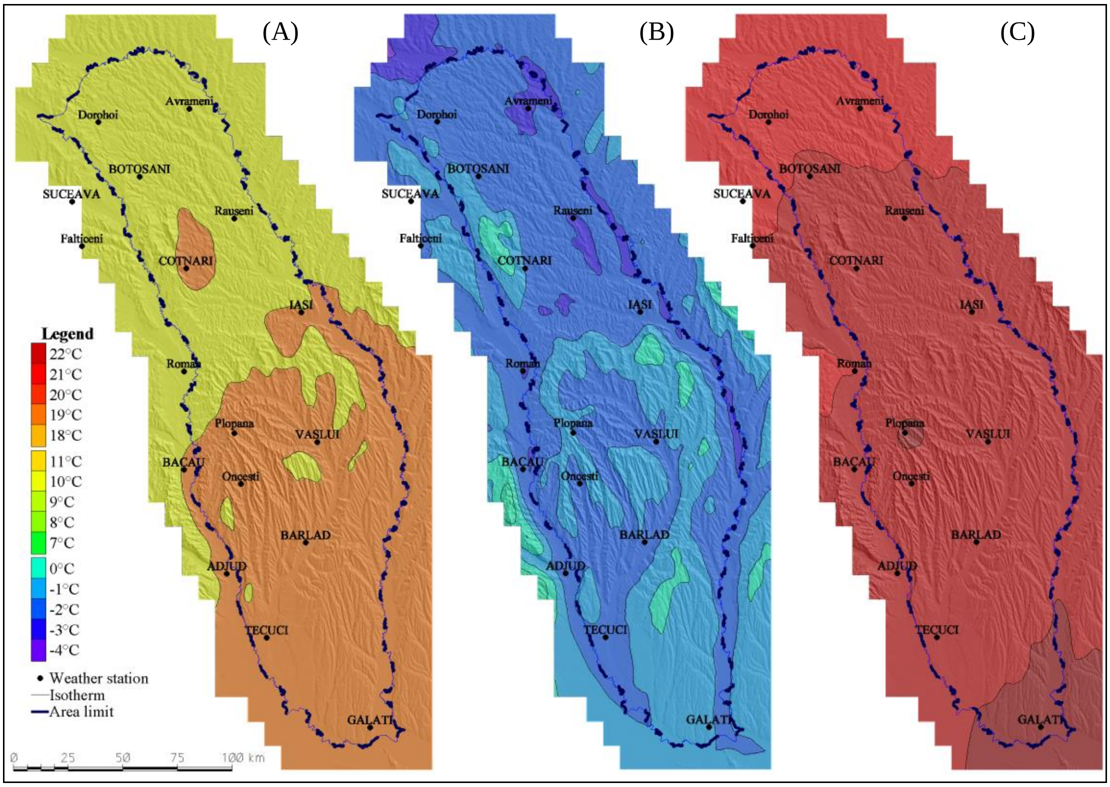

Figure 5: Temperature distribuiton: average multiannual reduced at sea level (A); January (B); July (C).

Termoisanomal distribution for multiannual average and characteristic months

Based on data regarding air temperature values reduce at sea level, average thermal values were calculated using horizontal thermal gradients, specific to the latitudinal range between 40-50° northern latitude. If the distribution of low average temperatures at sea level, the latitudinal factor was actively influencing the air temperature variation, in the case of thermal anomalies of air, reduced at sea level and having with the same altitude, a series of particularities of other factors are more clearly stated out. These particularities of other factors actively influence the distribution of average temperature values for the region contained between the rivers Siret and Prut.

In order to determine the thermal anomalies at multiannual level, the thermal gradient of 0.86°C/1° latitude was used. Thermal deviations from the annual average ranges from 0°C in the west part of the Moldavian Central Plateau, high area of Hârlău- Dealul Mare, Bălăbănești Hills and most part of Cuca Plain. The influence of the Black Sea as a shaping factor for the southern areas and the sheltered position behind the Carpathian chain that significantly reduces the influence of oceanic air masses up to the center of the Moldavian Central Plateau affects the central- southern region. Therefore, Jijia Plain Hill and central corridor of Prut river are characterized by positive thermal anomalies above 2°C (Figure 6-A). These anomalies represent a consequence of continental influences in small part but also of active influences of Atlantic air masses focused on the north part of the Carpathian Mountains (Apostol, 2004, Apostol & Sfîcă, 2011, 2013). The horizontal thermal gradient of January is about 1.23°C/1° latitude (Apostol, 1990). Highest anomalies exceeding 5°C are registered especialy in the far north of the region. The Carpathian arc and the active influence of atlantic air masses mark just as much the distribution mode of average termoisanomal for January, these values dropping to values under 1°C towards the southern third of the area (Figure 6-B).

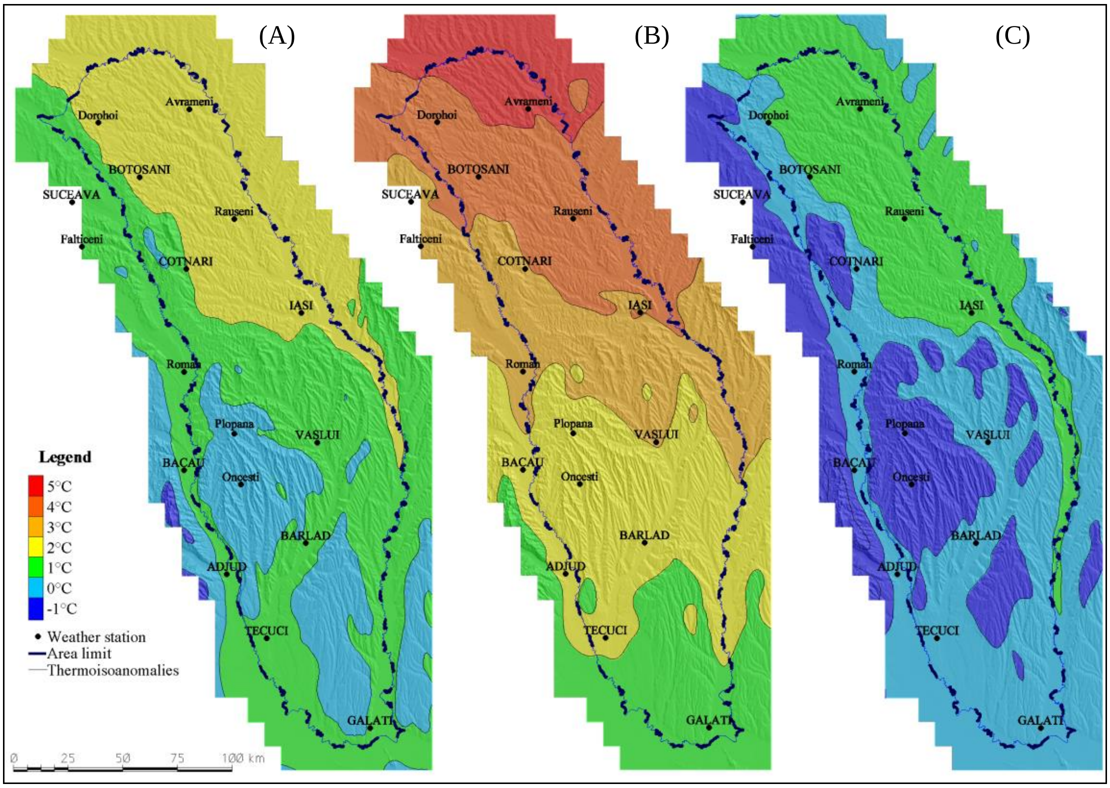

Figure 6: Average termoisanomal reduced at sea level: annual (A); January (B); July (C).

The high values of thermal anomalies in the north and approximately parallel distribution of termoisanomal on the NV-SE direction reflect the active influences of the atlantic air masses, deviated north by the Carpathian chain and fueled by the intense activity of Iceland mobile cyclones towards the south-east of the continent (Apostol, 1990, Apostol & Sfîcă, 2011, 2013). Southern decrease of thermal anomalies values is due to the extent of Siberian maximum pressure center that induces the formation of thermal inversion phenomena, but also the active influences of the Black Sea as a climate modeling factor. In July, thermal anomalies are somewhat blurred compared with January. Positive anomalies exceeding 1°C are specific to Jijia Plain and to central-northern area of Prut valley, anomaly generated by the continental influences (Figure 6-C).

Conclusions

The distribution of annual average termoisanomal and of characteristic months for the area contained between Siret and Prut rivers emphasizes the influence of morphological and morphometric factors on the general atmospheric circulation, and seasonal peculiarities of different active surfaces. Also it highlights the series of elements and local and/or general climatic phenomena such as: thermal inversion phenomena, föehn, differentiated channeling of air masses influenced by the relief, factors that have a major impact on air temperature distribution across Moldova territory and especially between rivers Siret and Prut.

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