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THERMAL DIFFERENTIATIONS INDUCED BY THE CARPATHIAN MOUNTAINS ON THE ROMANIAN TERRITORY

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Abstract: This study propose to bring new data and information about the way the Carpathian chain influences the temperature distribution on the territory of Romania. Among the effects of the Carpathian chain on the climate elements in Romania, we notice the development of the foehn processes of the Atlantic origin air masses east of the Carpathians, and also the barrier effect against the continental air masses that cannot advance west. For this, we comparatively analyzed the hourly temperatures for the 2001-2009 periods, registered at 4 weather stations, in the east (Iasi), south (Râmnicu-Vâlcea) and west (Cluj-Napoca şi Sibiu) of the country. The analysis was done on yearly, monthly and hourly data, leading thus to a general image of the thermal differences generated by the Carpathian Mountains. In this manner we have observed that the negative differences between Iaşi and Cluj-Napoca reach almost 30% of the hourly observations with a maximum of 42.7% in January. In the mean time the annual share of the same differences is just about 21.7% - with 29.9% in January - between Râmnicu-Vâlcea and Sibiu. Synoptic situations when the biggest differentiations occur were also analyzed.

Keywords: mountain obstacle, thermal differences, continental air mass, Carpathian foehn, Pearson correlation.

1. INTRODUCTION

The Carpathian chain has, on the Romanian territory, the most complex geological structure of all its length. In this sector, the mountainous chain has a width of more than 130 km and a curvature that suddenly modifies the peaks' orientation, from NNW-SSE in the sector of the Eastern Carpathians to E-W in the case of the Southern Carpathians. The morphometric discontinuity of the Western Romanian Carpathians does not allow them to determine major differences between the Pannonic Plain and the Transylvanian Plateau – due to the easy contact, through the Mureş Corridor and over the Someş Plateau – except those imposed by the different altitude of the two regions. Along with the higher altitude, in the Transylvanian Plateau, in winter, the cold air of the Siberian Anticyclone stagnates and it frequently produces cold air descents from the mountain frame. This way, the strongest thermal differences are induced by the united chains of the Eastern and Southern Carpathians, which divide Romania in two separate regions from the climate point of view (Bâzâc, 1974). The termic differences between these two regions are evident also in the global warming process, at the monthly and annual averages (Dragotă & Kucsicsa, 2011; Piticar & Ristoiu, 2012).

From a morphometric point of view, altitudes are high enough to form an orographic obstacle, very efficient for both the continental air masses that come from the east of the continent and for the Atlantic ones that come from the west; this way, the climatic influence of the Carpathians manifests not only in the mountainous region, but on the entire Romanian territory (Donisă & Davidescu, 1972). The Eastern Carpathians are characterized by morphometric continuity, in spite of the altitudes that do not exceed 1500 m at the ridges level. Also, the lowest altitude along the mountain passes is of over 600 m. The Southern Carpathians, on the other side, have the highest altitudes of the Romanian Carpathians, of over 2500 m, but this sector is transversally cut along by the Olt River Valley, at an altitude lower than 300 m approximately and by the Danube at an altitude under 100 m. On these valleys, though, especially on the Olt River Valley, the high length and the narrowness of the corridors as well as the system of local winds, mountain breezes, do not allow the penetration of the air masses from one side to the other of the Carpathian area chain. Sometimes, on the Danube Valley, which is wider, and placed in a low of the Carpathian arc, massive movements of the air masses take place, submediterranean from the west and continental from the east.

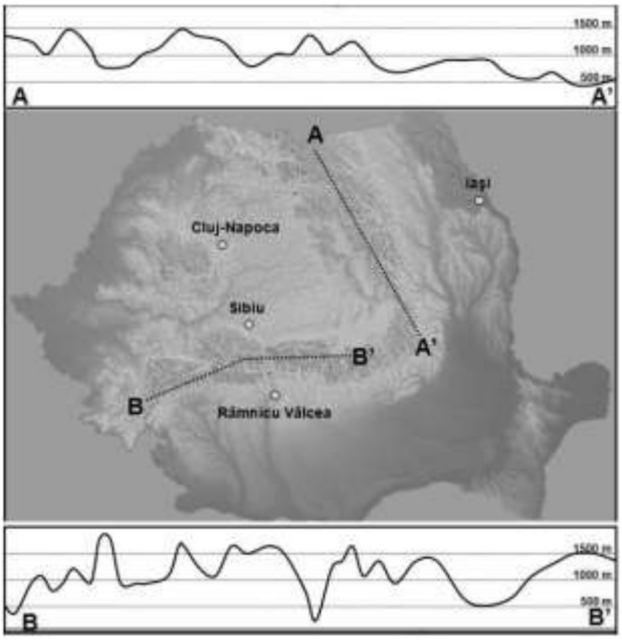

Figure 1. Topographic profile along the Romanian Carpathians and position of the weather stations used for the thermal differences analysis

That movement sometimes generates a foehn wind, which is more frequent in the western part of the Carpathians (Coşava). Despite this, the existence of these transversal corridors along the two transcarpathian valleys reduces some of the orographic barrier role, complicating the distribution of the climatic elements on the two sides of the mountain ridge, while the Eastern Carpathians can create, by altitudinal continuity, higher thermal contrasts between Moldova and Transylvania (Fig. 1). The major relief and the Black Sea impose a few characteristics to the general circulation, predominantly western. Western circulation, frequently foehnized and that of north-west, over the Someş Plateau, are characteristic for Cluj Napoca. In Iaşi, the north-west dominates, derived from the western circulation twisting, along the Ukraine curvature of the Carpathians (Apostol & Sfîcă, 2011) and the eastern one, generated by the baric maximums of the east of the continent. North of the Southern Carpathians, in Sibiu, western circulation is guided to the Carpathians curvature. In Râmnicu Vâlcea, south of the Southern Carpathians, the east-west transition circulations predominate, with south-western, submediterranean intercalations and channelings on the Olt River Valley, north-south.

2. METHODOLOGY

Searching to underline the thermal differences induced by the Carpathian chain, in this study, we analyzed and compared the temperatures at the local hours 02, 08, 14 and 20 in Sibiu, Cluj-Napoca, Râmnicu-Vâlcea and Iaşi, at a daily level, for the 2001-2009 period. The data series were downloaded from http://meteo.infospace.ru where the meteorological observations are collected worldwide on the basis of official synoptic reports (for Romania the data come from Romanian Meteorological Administration observation network). These data were analyzed in pairs, to discover both the influence induced by the Eastern Carpathians (comparison between Iaşi and Cluj-Napoca), and that induced by the Southern Carpathians (comparison between Sibiu and Râmnicu Vâlcea) on the temperature distribution on the Romanian territory. Then, we selected the cases in which the hourly thermal difference between the two stations was higher than 3ºC, in favor of one or the other station, as an expression of major thermal contrasts possibly induced by the Carpathian chain.

Although the weather stations used are placed at fairly different altitudes (100 m in Iaşi compared to 400 m in Cluj-Napoca and 100 m in Râmnicu-Vâlcea, compared to 300 m in Sibiu and different latitudes, generating theoretical average thermal differences of 1.8°C and 1.2°C (at an yearly level), we did not convert the temperature values in the sea level temperatures, because thermal gradients of the inferior troposphere on the territory of Romania are inconstant during the year, being strongly influenced, especially in the cold season, by thermal inversions (Apostol, 1988, Apostol, 1990). This way, according to the data from Clima României, 2008, the difference between the yearly average temperature in Iaşi and Cluj-Napoca is of only 1.4°C, compared to the 1.8°C that it would have to be if the normal thermal gradient of 0.6°C/100 m in the inferior troposphere would be respected. The situation is the same in the case of the differences between Sibiu and Râmnicu-Vâlcea.

Based on the synoptic materials available on Deutscher Wetterdienst Archive, found on www.wetter3.de, synoptic conditions when these thermal differences occur were identified. For this purpose, time intervals sufficiently persistent in time were selected, to keep, as much as possible, only the dynamic situations and to exclude from the analysis those with a solely radiative origin. For this reason, we extracted those intervals where the difference between the diurnal average temperatures at the stations was higher than 3ºC for at least 3 consecutive days, selecting this way the contrasting periods that were persistent enough. In the end, the typical synoptic conditions when these differences occur were established.

3. RESULTS AND DISCUSSIONS

As the Carpathian chain constitutes a barrier in the air masses propagation, this fact is reflected in a discontinuity of the air temperature field on the Romanian territory. For this, we calculated the values of the Pearson correlation coefficient between the air temperature at the four hours for each of the two pairs of weather stations (Iaşi-Cluj Napoca, Râmnicu Vâlcea-Sibiu). Starting from the premise that the low values of this coefficient reflect major discontinuities in the field of the air temperature on the Romanian territory and that these are explained mainly by the barrier imposed by the Carpathians, we can identify the period of the year and of the day when the Carpathian chain acts more efficiently to this end (Fig. 2). We can notice this way that the simultaneity degree in the air temperature evolution is higher for Iaşi-Cluj Napoca than for Râmnicu Vâlcea-Sibiu, despite the greater distance between the first two stations. Taking into account this situation, we could conclude that the sector of the Southern Carpathians acts much more efficiently as an orographic barrier against the air masses propagation than the Eastern Carpathians, which proves that the transcarpathian valley of the Olt River does not constitute an axis along which the change of air masses between the inner and outer Carpathian regions occurs.

3.1. Differences determined by the Eastern Carpathians

The negative differences between Iaşi and Cluj Napoca, at diurnal level, have an yearly share of 29.7%, with the maximum in January, of – 42.7% and the minimum in July, of -15.3%. The monthly frequency of this type of differences exceeds 25% from October till April, being situations characteristic mainly to the cold season of the year, when the east of Romania can be frequently under the action of the cold air masses of polar continental origin (Fig. 3). At an hourly level, the differences >3ºC are the most frequent – more than 20% of the observations – in the cold season, in the 15-18 hours interval, when the diurnal maximums remain much lower at the exterior of the Carpathians, under the influence of the colder air masses frequently accompanied by a stratiform nebulosity that blocks the radiative heating (Sfîcă, 2010).

The big negative diurnal differences between Iaşi and Cluj-Napoca occur especially in the case of the eastern circulation. The frequency of differences >3ºC is of only 2.2 % of the analyzed interval, ¾ of the cases being concentrated in the December-February period. In these situations, the polar-continental air masses, extremely cold, remain east of the Eastern Carpathians, not being able to cross the mountain ridges because of their continuity, but also because of their reduced vertical development (Donisă & Davidescu, 1972). In the same work, the author underlines the fact that these kinds of differences also occur when the warm air easily enters in Transylvania, but cannot dislocate the cold air of the low extracarpathian regions. In these situations, the difference between the air temperature in the extracarpathian regions and those inside the Carpathian arc can reach 15-20°C (Stăncescu, 1983). For the analyzed period, the maximum difference of this type between the two weather stations was of 18.5ºC and it occurred on February 24, 2007 at 8 a.m., when in Iaşi there were -19.3ºC, while in Cluj-Napoca the temperature was of just -1.1ºC (Fig. 4-a). The same differences appear, much more rarely, in the situation of a northern circulation, when the Eastern Carpathians and the Ukraine Carpathians block the entrance of the cold air inside Transylvania, the action of the cold air mass remaining limited to the region at the east of Carpathians.

The positive diurnal differences between Iaşi and Cluj-Napoca, at a diurnal level, have an annual share of 70.3%, the monthly frequencies exceeding 80% from May till September (84.5% in July) and going down up to 57.3% in January.

This higher share of positive differences explains the annual difference between the average temperature in the two cities (9.6ºC in Iaşi and 8.2ºC in Cluj-Napoca, according to Clima României, 2008) and underlines that this difference is the result of the situations in the warm period of the year. Besides, in the October-April period, the average temperatures at the two stations are very similar, even if it should be warmer in Iaşi. This happens because in Iaşi the Euro-Siberian Anticyclone and the thermal inversions are more frequent, while in Cluj Napoca, those air masses are not so oft well received. At diurnal level, differences of more than 3ºC occur more frequently in the first part of the day, between 5-12 a.m., from June till October (more than 32% of the number of observations), which means that the diurnal minimums are much lower in Cluj Napoca than in Iaşi during the warm season (Fig. 3).

Extreme opposite differences, when temperatures in Iasi are higher with more than 3ºC than in Cluj-Napoca, selected according to the methodology – with a share of 6% of the entire analyzed period – occur especially in radiative conditions, as there is a big altitude difference between the two observation points. The maximum difference of this type was of 16.5ºC on July 3, 2007, at 14 hours, when in Iaşi 34.1ºC were registered, while in Cluj-Napoca the temperature was of 17.6ºC but that values is irelevant for our study being determined by thunderstorm conditions in Cluj-Napoca. Nevertheless, there are also dynamic situations that lead to the same type of differences.

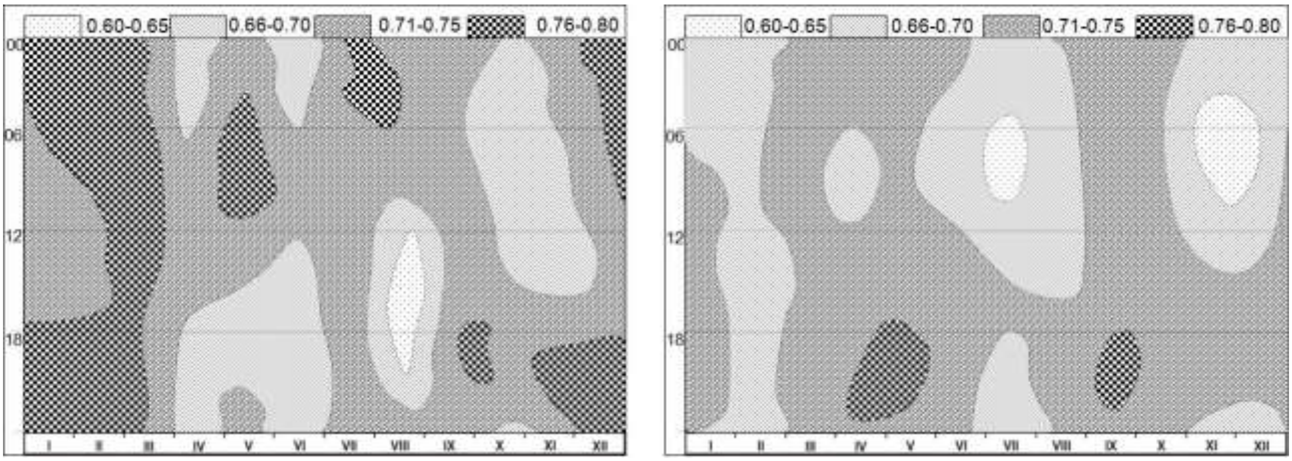

Figure 2. Isopleths of the Pearson correlation coefficient calculated between the hourly temperatures of Cluj-Napoca and Iaşi (left) and Sibiu and Râmnicu Vâlcea (right)

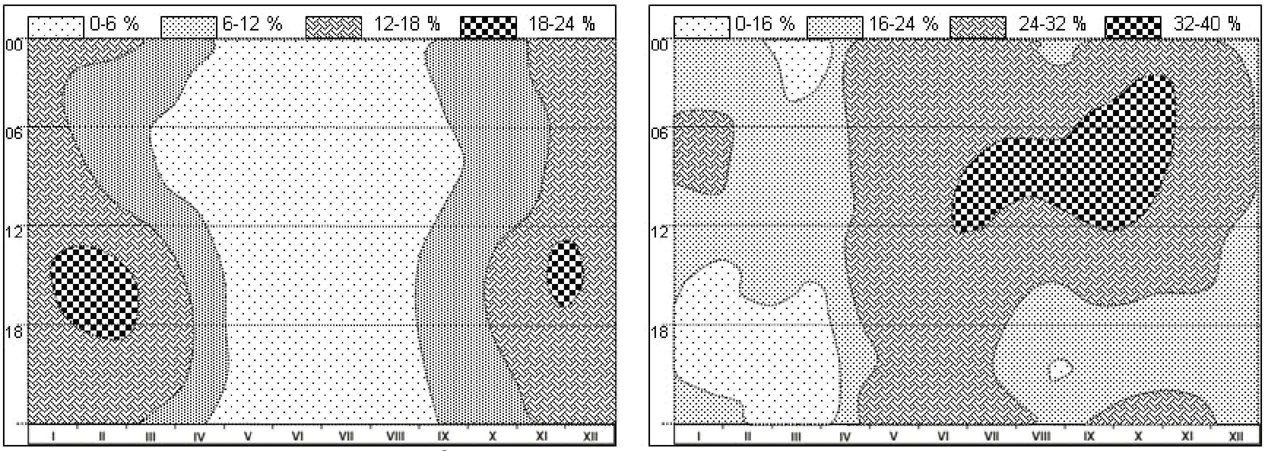

Figure 3. Isopleths of the frequency of >3^{o}C differences between the hourly temperatures in Cluj-Napoca and Iaşi (left) and Iaşi and Cluj-Napoca (right)

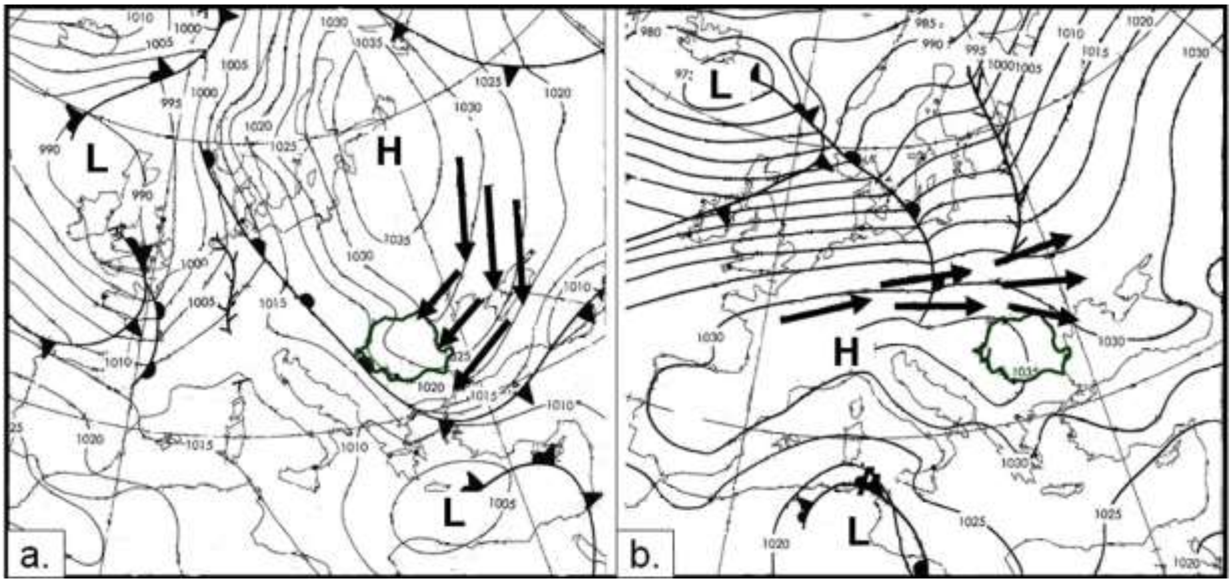

Figure 4. Synoptic conditions favorable to the occurrence of big thermal differences (>3°C) on the Cluj-Napoca – Iaşi profile (a.- 24.II.2007) and Iaşi - Cluj-Napoca (b. – 14.XII.2006) –Deutscher Wetterdienst Archive

This happens in the case of the western circulation during winter, when the Atlantic warm air masses enter without encountering obstacles on the north of the Carpathians arc, being then deviated towards south, to Moldova, while Transylvania remains under the influence of the colder air masses, previously existing above all Romania (Fig. 4-b). For example, in the December 14-17, 2006 period, in the above mentioned synoptic conditions, a difference of 10.1°C at 2 p.m. was registered, on December 16, when in Cluj-Napoca there were -2.0°C while in Iasi, due to the warm Atlantic air advection, 8.1°C were registered.

3.2. Differences determined by the Southern Carpathians

Negative differences between Râmnicu-Valcea and Sibiu, meaning higher temperatures on the northern ridges of the Southern Carpathians than on the southern one, have an annual share of 21.7%, with a maximum frequency in January – 29.9% and a minimum one in August – 10.4%. The frequency of these situations is higher than 20% at a monthly level in the November-May period. At a diurnal level, the highest frequency of the differences of more than 3ºC is reached in the 5-13 hourly interval from December till February, while in July and August these situations are completely absent (Fig. 5).

Positive daily differences between Râmnicu-Vâlcea and Sibiu, meaning lower temperatures on the northern ridges of the Southern Carpathians than on the southern one, have an annual share of 78.3%, the monthly maximum frequency exceeding 80% from June to October (89.6% in August), and the monthly minimums are reached during the winter months (70.1% in January). This high percentage of positive differences also explains the big differences between the annual average temperatures of the two stations (10.2ºC in Râmnicu Vâlcea compared to 8.9ºC in Sibiu). At a diurnal level, the frequencies of the differences >3ºC of this kind can be found mainly during the afternoon hours in February-March, when they reach a share of 40-50% of the hourly values; this underlines the position of orographic shelter of the region south of the Carpathians against the cold air waves that remain limited only to the interior of the Transylvanian Plateau and the role of the exposure in the case of reduced nebulosity.

The cases when temperatures in Sibiu are 3ºC higher than those in Râmnicu Vâlcea have a small share (Fig. 5). Only 62 days of the 9 analyzed years have these characteristics. These types of situations are mainly marked by southern circulations (9 of the 13 intervals of this kind identified in the studied period occur in these conditions). Most frequently, synoptic maps indicate the presence of a Mediterranean cyclone centered in the west of the Balkan Peninsula, which determines o strong southern advection over Romania (Fig. 6-a). This advection leads to the development of the foehn wind on the northern ridges of the Southern Carpathians; this phenomenon is also highlighted by the rotor clouds presence on the Modis satellite images (Fig. 6-b), clouds that are characteristic to the manifestation of the phenomenon (Ion-Bordei, 1988). In these situations, the maximum difference between the two stations reached 14.1ºC on December 9, 2006, at 2 p.m., when in Sibiu there were 15.6ºC and 1.4ºC in Râmnicu Vâlcea (fig. 5-a). We mention that in the Romanian climatology literature, the Sibiu lowland is not indicated as a place in our country where the foehn manifests itself, in none of the many of the works dedicated to the this wind (Bogdan & Mihai-Niculescu, 1990). Most of these situations are concentrated in the November-February period (3/4 of the total number of cases), due to the more frequent action of the Mediterranean cyclones in this period of the year, many times on routes deviated from the classic Pannonian routes. These contrasts are generated also by the entrance of the continental cold air from the east of the continent, south of the Carpathian arc, in the Romanian Plain (Stăncescu, 1983), determining temperature decreasing up to the low regions of the Getic Subcarpathians, while sheltered by the Carpathians arc, in Transylvania, temperatures remain higher.

Temperatures >3ºC in Râmnicu Vâlcea compared to Sibiu are much more frequent (7.9% at yearly level), due to the lower altitudes of the Râmnicu Vâlcea weather station (Fig. 5). Approximately 29 of these days are registered annually. From a synoptic point of view, these situations occur most often in conditions of northern circulation in Romania, and they are determined by ridges of high pressure extended over the central-western part of the continent. This time, thermal contrast is no longer determined by the foehn descend and by the mountain chain blocking of the cold air masses that enter from north inside the Transylvania Basin, while the regions south of the Carpathians remain warmer. The maximum difference in these cases was of 15.1°C, on August 24, 2008 when in Sibiu 17.9ºC were registered and 33.0ºC in Râmnicu-Vâlcea. The same thermal contrasts can develop also in western circulation conditions. The persistence of the anticyclone conditions determines also the appearance of the fog in the Transylvania Basin, a phenomenon that maintains the big temperature differences between the two sides of the mountain frame.

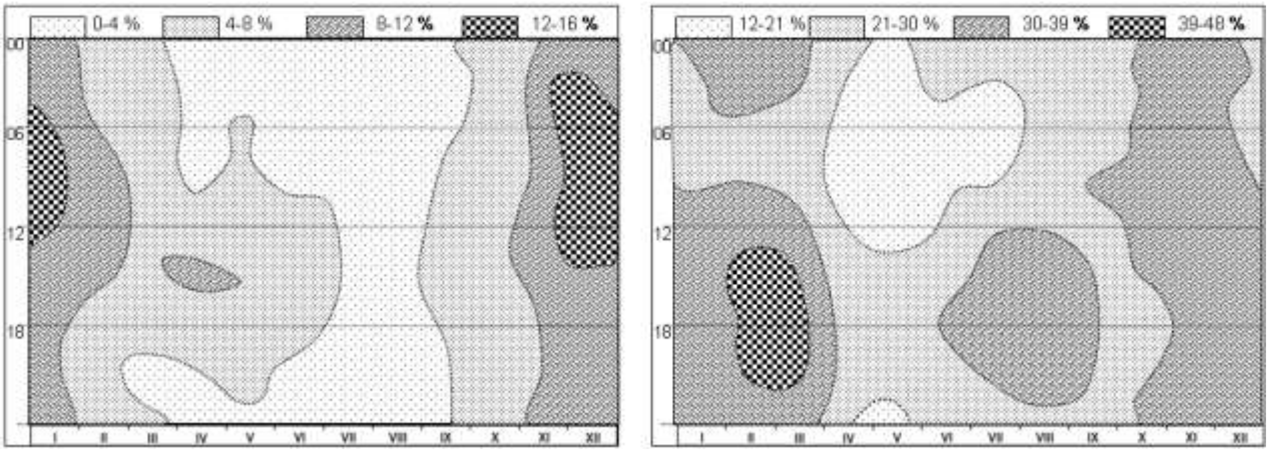

Figure 5. Isopleths of the frequency of >3°C differences between the hourly temperatures in Sibiu and Râmnicu Vâlcea (left) and Râmnicu Vâlcea and Sibiu (right)

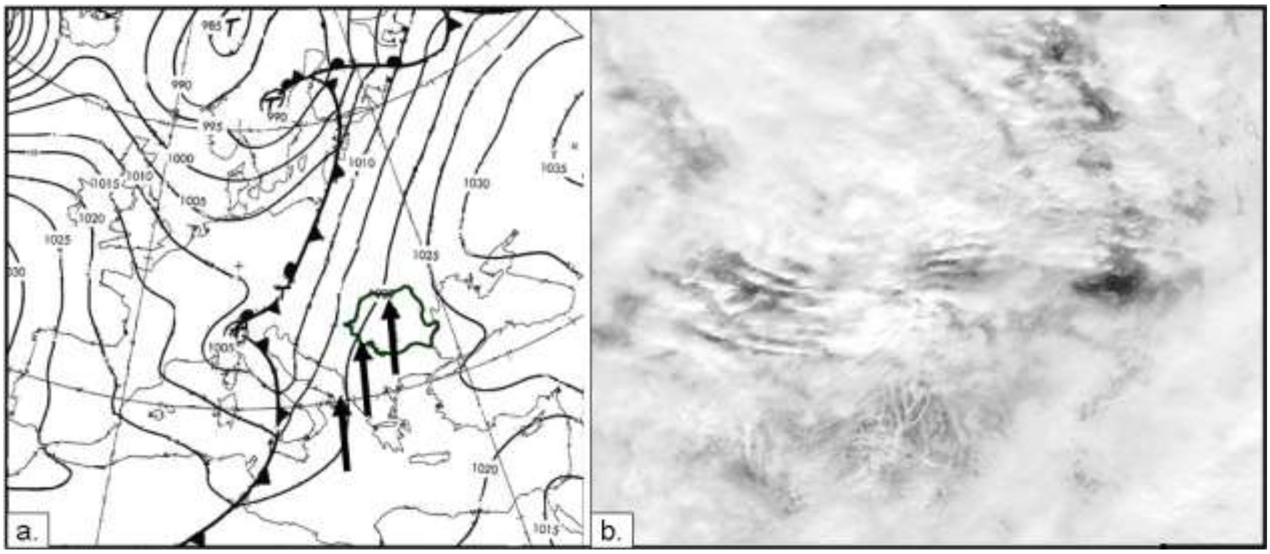

Figure 6 - Synoptic conditions favorable to the occurrence of big thermal differences (>3°C) on the Sibiu – Ramnicu-Valcea profile (a.- 9.XII.2006) and the Modis satellite image that indicates the rotor clouds presence (b. - 23.XII.2009) - Deutsche Wetterdienst Archive, Modis satellite image

4. CONCLUSIONS

The results of our study attest that the Carpathian chain represents one of the most important climatic barriers on the European territory.

Carpathians introduce significant discontinuities in the air temperature distribution in the Romanian geographic region during the whole year; these are in favor of the exterior of Carpathian arc in the warm semester of the year, while in the cold semester, polar continental air masses have a stronger action in the same extracarpathian regions. Based on this founding, the main conclusion of this study is that the milder climate of the intracarpathian regions is not so much a result of the high frequency of the Atlantic air masses, but a result of the orographic shelter that the Carpathians create for these regions, especially against the polar continental air advections arrived from the east of Europe in winter.

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