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THE COMPARATIVE ANALYSIS OF THE THERMAL REGIME IN THE RUCĂR-BRAN CORRIDOR AND THE PRAHOVA-TIMIŞ CORRIDOR

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Abstract. Comparative analysis of thermal regime in the Rucăr-Bran Corridor and the Prahova-Timiş Corridor. The authors analyze the thermal regime of two close corridors – one in the mountains and one in a valley; the first one – the Rucar-Bran Corridor is situated in the east of the Southern Carpathians e separates the Bucegi group from the Fagaras group; the second – the Prahova Timis Corridor is situated at the contact between the Southern and the Eastern Carpathians, between the Bucegi-Postavaru Mountains and Teleajenului Mountains. In order to determine from a thermal point of view the similarities and the differences between the two negative landforms, the authors used the vertical temperature gradients on the northern, southern, eastern and western slopes, based on the annual average temperatures and of the two characteristic months of the year (January/February and July/August) from seven weather stations installed in the region, at altitudes between 461 and 2504 meters, for a 47 year period (1961-2007). This way, they discussed the temperature differences in winter and summer between the mountain peaks and the depression areas, as well as the thermal anomalies caused by the geographic location: the position of the corridors' regions with regard to the main atmospheric circulation and the exposure of the slopes to the sun, as well as the landform, which can alter the general distribution of the air temperature on the vertical.

Introduction

Knowing varriation of climatic elements such as the air temperature is of great importance in solving some issues raised by the various fields of national economy, especially tourism. This is because Rucăr-Bran and Prahova-Timiş Corridors are first rank tourist regions in Romania, with old traditions in this regard. About

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climate of two corridors so far a number of climate studies have been developed (see bibliography), among which two PhD theses (Teodoreanu, yet 1980; Mic, 2012) which allowed the possibility of comparing from a geographical mostly climatic standpoint the two nearby mountain regions, attempting in this way to emphasize the similarities and differences between them.

1. Study area

The two negative forms of relief, or the so-called „geographical discontinuity areas" (Mihăilescu, 1963), bound the Bucegi Massif being located on it's both sides (Fig. 1).

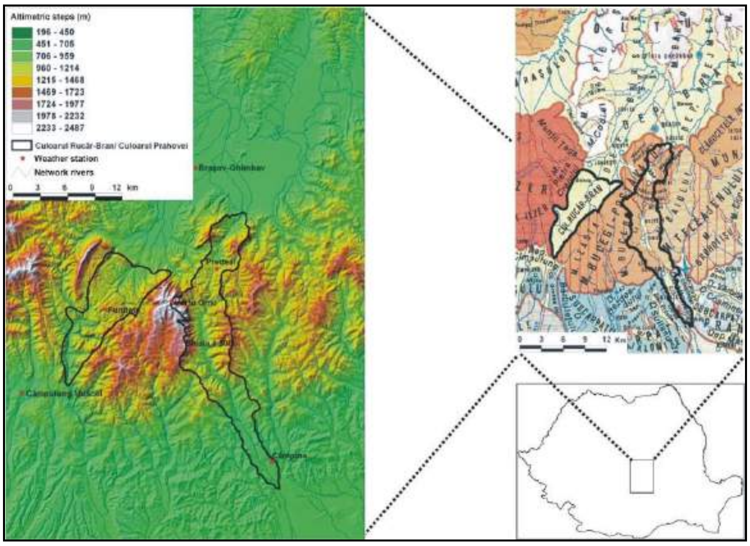

Fig. 1 - Location of meteorological stations and study area

Located in the western part of the Bucegi Massif, the Rucăr-Bran Corridor, compared to the highest altitudes in this massif (Omu Peak, 2504 m altitude) enhances the topoclimatic features which are different from those of the Prahova Corridor. Being a transverse mountain corridor, with an opening to the northeast and southwest respectively behind and in front of the orographic dam of Carpathians, Rucăr-Bran links the Bârsa Depression (Braşov Depression), north of the Carpathians, and the Câmpulung Depression (Muscelele Argeşului), south of them, therefore it is wide open for air masses from the north and northwest respectively south and southwest. Inside there are relatively small depressions (Dâmbovicioara, Podul Dâmboviţei and Rucăr) that differentiates between them by climate characteristics topoclimatic under the direct influence of the mountain

(Teodoreanu, 1980). Same as Rucăr-Bran Corridor, the Prahova-Timiş Corridor is bound at both ends by two well-developed depressions (Braşov Depression, on north side and Câmpina, on its southern side), so that north – south is the predominant movement direction of air masses.

Also within the Prahova-Timiş Corridor there are few generally small depressions (Săcele Piedmont, Timiş Depression, Sinaia Depression, Comarnic-Breaza Depression, Brebu and Câmpina) whose topoclimatic and climate characteristics are still under the influence of the mountain, but also of the surrounding hills, slightly tinted by the foehn effects from the Curvature region (Prahova Corridor being at the west end of it), occurring on the southern slopes, crossing the masses of wet and unstable air from the north and northwest.

Therefore, the presence mountain and hill peaks with different orientations and altitudes, which bound depression areas, have a significant influence on the climate of the valley and the mountain corridor.

2. Data and methods

The comparative analysis of the thermal regime in the Rucăr-Bran Corridor and the Prahova-Timiş Corridor was based on monthly and annual data recorded at 7 meteorological stations (located between about 400 and >2500 m) (Fig. 1), during the period 1961-2007.

To have a clear picture of the variation of air temperature with altitude, mainly ***the vertical thermal gradient values both at year level and thermally characteristic month level*** were looked at.

The temperature differences obtained (Δtº C) for meteorological stations located on the northern, southern, eastern or western slopes, but also on the Prahova slope or the one between the stations Sinaia 1500 and Predeal (table 1) were the data used or the comparative analysis of the vertical thermal gradients in the two mountain corridors. At the same time, the statistical significance of the trends of variation of air temperature was determined through the Mann-Kendall test (Sneyers, 1975; Salmi et. al., 2002; Tomozeiu et. al., 2005), setting as statistical significance threshold level of ≥ 90% (Micu, 2007-2008).

3. Results

A number of climate parameters highlight the local heat potential of the two mountain corridors.

3.1. The average annual temperature

Based on analyzed meteorological stations one can conclude that, on similar morphological conditions, the temperature variation has similar features (Fig. 2). A summary analysis of the ***distribution map of annual average temperatures*** for a period of 47 years (1961-2007) reveals that the highest values of te isotherms (7-9ºC) characterizes the southern extremity of Prahova Corridor, southern outskirts

Tab. 1 - Vertical thermal gradients in the Rucăr-Bran and Prahova-Timiş Corridors

Slopes types	Weather station	Δ h m	Δ t (ºC) Med. t. an	ºC/100 m	Δ t (ºC) Average temperature of the coldest month	ºC/100 m	Δ t (ºC) Average temperature of the hottest month	ºC/100 m
North slope	Omu Peak – Braşov-Ghimbav	1970	10.0	0.51	5.9	0.30	12.3	0.62
	Predeal – Braşov-Ghimbav	556	2.6	0.47	0.5	0.09	3.4	0.61
	Fundata – Braşov-Ghimbav	850	3.2	0.38	0.8	0.10	4.3	0.51
North slope average				0.45		0.16		0.58
South slope	Omu Peak – Câmpina	2043	11.4	0.56	10.0	0.42	13.9	0.68
	Omu Peak – Câmpulung	1923	10.5	0.51	12.4	0.40	12.5	0.61
	Predeal – Câmpina	629	4.0	0.64	3.1	0.48	4.9	0.78
	Fundata – Câmpulung	703	3.7	0.52	3.0	0.43	4.4	0.62
South slope average				0.56		0.43		0.67
Eastern slope	Omu Peak – Fundata	1120	6.8	0.61	5.1	0.46	8.0	0.71
Western slope	Omu Peak – Predeal	1414	7.4	0.52	5.8	0.41	8.9	0.63
Prahovean slope	Omu Peak – Sinaia 1500	994	6.2	0.62	5.5	0.55	7.0	0.71
	Sinaia 1 500 – Predeal	420	1.2	0.29	0.3	0.07	1.9	0.44
General average				0.52		0.30		0.63

** Source: Calculated data based on the ANM Archive.*

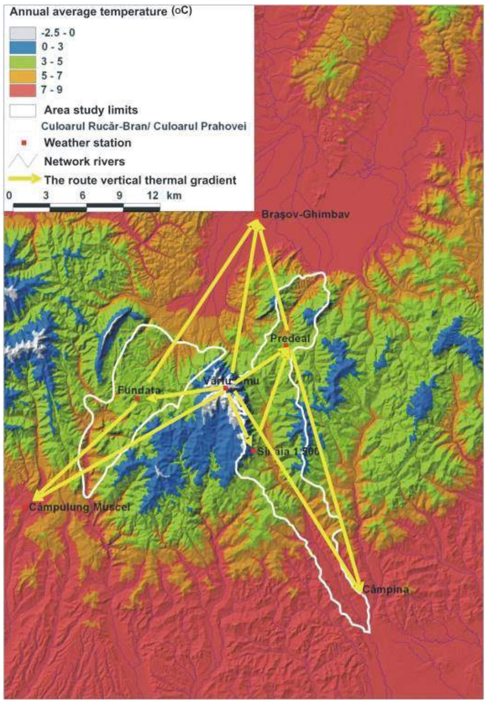

Fig. 2 - The territorial distribution of annual averages air temperature and vertical temperature gradients route

Rucăr-Bran and the northern one of the entire territory, so in general, the regions located at altitudes <800 m. Average annual values of the isotherms decrease as the altitude increases to about 2500 m. Thus, in both mountain corridors, between 800 and 1000 m altitude, they vary between 5º-7ºC.

3.2. Vertical thermal gradients

Instead, isotherms at between 3º-5ºC characterizes most of the Rucăr-Bran Corridor and only the Carpathian sector of the Prahova-Timiş Corridor with altitudes between 1 000 and 1 600 m. Between 1 600 and 2 000 m, isotherms have values between 0º-3ºC, and at over 2 000 m altitude, they have the lowest values (-2.5º…0ºC). Interesting aspects arise and if we look at average annual vertical thermal gradients route and from the thermal characteristics months (Tab.1, Fig. 2).

Since we aim to show, first the role of atmosphere general circulation and then of local geographical features, we chose six cross sections (Figure 3-8), which crosses the western slopes of the exhibition, eastern, northern and southern, and prahovean or the slope of Sinaia 1500 and Predeal. Sinaia 1500 sation, located 75 m above the bottom of the Prahova Valley has a typical geographical position, being located on a spur of storeyed ground (Stoenescu, 1951). However, a prolonged period of meteorological observations for over 40 years has allowed its thermal data comparison (synchronous intervals) with the meteorological station of Predeal, located in different conditions of relief. The Rucăr-Bran and the Prahova Corridors are characterized by considerable variations in vertical temperature gradients due to local morphological conditions, differences in altitude and especially the dominant pattern of air circulation, so that in the table above, which show the vertical thermal gradients, the ***average level differences (Δhm)*** for slopes with different exhibitions were included.

Fig. 3 - Profile I – western slope

Annually, ***the temperature difference (ΔtºC)*** between the highest peaks of the Bucegi Massif and the surrounding lowlands ranges between 10.0º…10.5ºC (Omu Peak –Braşov-Ghimbav respectively Omu Peak-Câmpulung Muscel) and 11.4ºC (Omu Peak and Câmpina). The eastern and western slope, and the slope of

Prahova, this difference varies between 6º-7ºC, while on the north side and south, it is equal to or below 4ºC (Table 1).

The overall average values of annual average vertical thermal gradient in the entire analyzed area is 0.52ºC; in ***summer***, increases to 0.63ºC, but in ***winter*** drops to 0.30ºC. It maintains its value and on the western slope (between Omu Peak and Predeal) (Figure 3) at both annually and in the hottest month of the year, but in winter, compared to the overall average of the region, it increases by up to 0.41°C/100 m.

For the ***Eastern slope (between Omu Peak and Fundata)*** (Fig. 4) vertical thermal gradient values are comparable to those recorded on the ***Prahova slope*** (***between Omu Peak and Sinaia 1500***) (Fig. 5), meaning that for every hundred meters, the temperature decreases in ***summer*** also by 0.71ºC, and the ***annual level*** of 0.1ºC higher, up to the value of 0.61°C/100 m. Larger differences are during the winter, when in January, the values of thermal gradient vertical fall to 0.46ºC/100 m, by aprox. <0.10ºC higher.

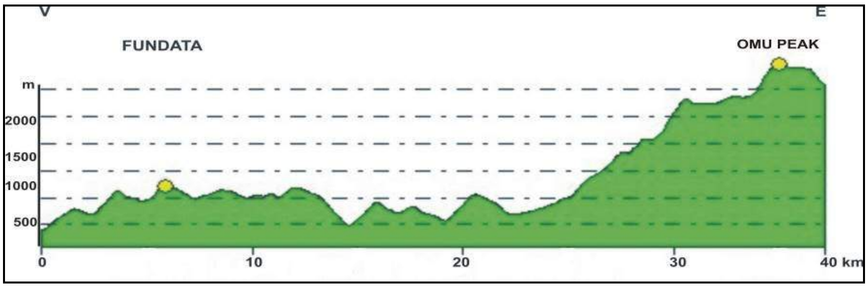

Fig. 4 - Profile II – Eastern slope

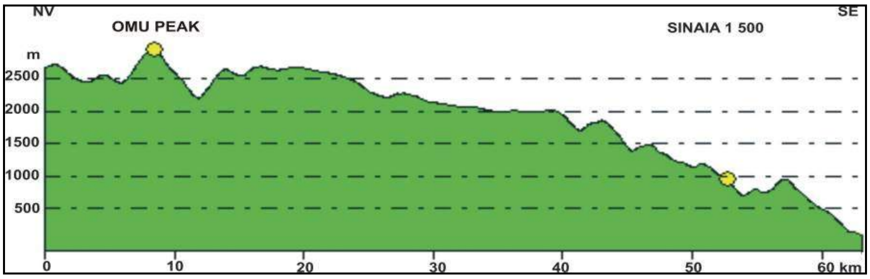

Fig. 5 - Profile III – Prahova slope

If we follow ***the variation of vertical thermal gradients on the northern and southern slopes*** of the analyzed area (Table 1, Fig. 2, Fig. 6), except that the ***annual temperature gradient route*** of Omu Peak-Braşov stations on the northern slope (Fig. 6) have equal values (0.52°C/100 m) with those of Omu Peak-Câmpulung Muscel meteorological stations on the southern slope (Fig. 7) – generally, the thermal gradients established using the meteorological stations ***are lower on the northern slope than on the southern one due to the temperature inversions during the winter.*** In this case, the differences can reach up to 0.17-0.18ºC/100 m in average.

Fig. 6 - Profile IV – north side

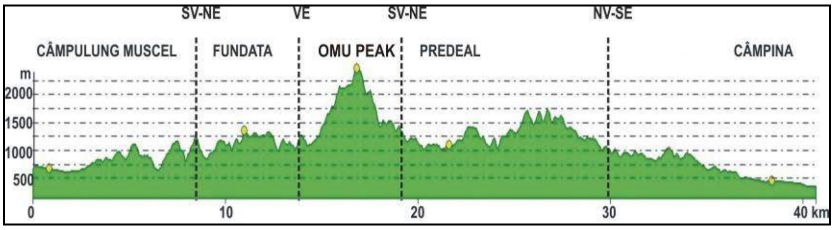

Fig. 7 - Profile V – southern slope

During ***the coldest month of the year***, more than the annual values, differences in temperature distribution on the northern slope and the southern one are noted (Table 1). The thermal gradients are very low in the first case i.e. 0.09-0.10ºC/100 m between Predeal and Braşov-Ghimbav and between Fundata and Braşov-Ghimbav, which highlights the intense and persistent inversions in this part of the analysed area and the relatively high, in the second case, 0.40-0.48ºC/100 m, slightly lower than the annual ones, as a result of weaker and shorter inversions (Teodoreanu, 1980).

The vertical gradients of the hottest month on two types of slopes range between 0.51ºC/100 m ***on the northern slope*** and 0.68ºC/100 m ***on the southern one***, showing a more obvious warming of the southern slopes and a deep cooling as the altitude increases, and on the other hand, favorable conditions for the existence of thermal inversions towards Brasov Depression, even during the warm season. Very pronounced is the thermal gradient between Predeal and Câmpina namely

0.78ºC/100 m, highlighting a more rapid cooling as the altitude increases (Teodoreanu, 1980).

Between Sinaia 1500 and Predeal stations (Fig. 8) vertical thermal gradient values (Table 1) decrease on average per year by 0.29º-0.44ºC/100 m – during the summer and during the winter by only 0.07°C/100 m whereas in Predeal, the horizon is cleared towards west and the morphological opening between Bucegi and Postăvaru through Râşnoavei Valley makes the overall direction given by the upper Prahova Valley in the region of origin to shape the route of the vertical thermal gradients in this part of the analysed area.

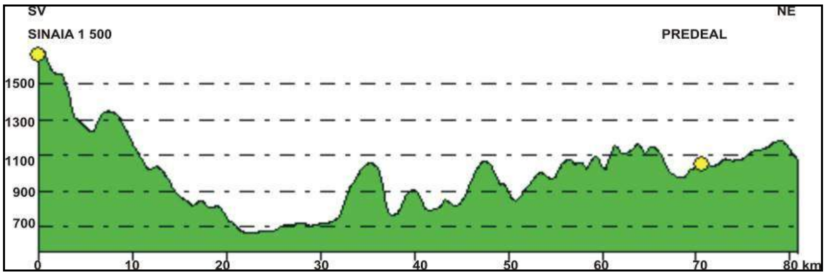

Fig. 8 - Profile IV – Sinaia1 500-Predeal

3.3. The average monthly air temperatures

From ***the territorial distribution of the average annual values of air temperature in the coldest month of the year***, it appears that in most of the analyzed territory with altitudes <1200 m, the isotherms have values >-5ºC (Fig. 9). On a small portion of the Rucăr-Bran and only in the Prahova-Timiş Carpathian Corridor at altitudes between 1 200 and 1 800 m, the values fall to-10ºC. Between 1 800 and 2 000 m, isotherms have values between-10.1...-10.5°C and at over 2 000 m altitude, the values drop to about -11ºC.

If we analyze ***the vertical thermal gradients*' *route*** (Table 1, Fig. 9), it appears that in winter in the coldest month of the year, large temperature differences occur only on the southern slope between stations Câmpina and Omu Peak respectively between Omu Peak and Câmpulung when ranges from 10-12ºC; otherwise they remain below 6ºC or even having below par values.

The average temperature of the warmest month shows a spatial distribution as varied as that of the coldest month of the year, but the temperature difference between high mountain peaks and surrounding lower regions increases substantially (Table 1).

The multi-annual variation of air temperature in the warmest month of the year at different altitudes is not the same. Thus, out of the territorial distribution of the climatic parameter (Fig. 10) results that the July isotherms' values >18°C are characteristic for both mountain corridors and their surrounding regions in the south and north, with altitudes <800 m.

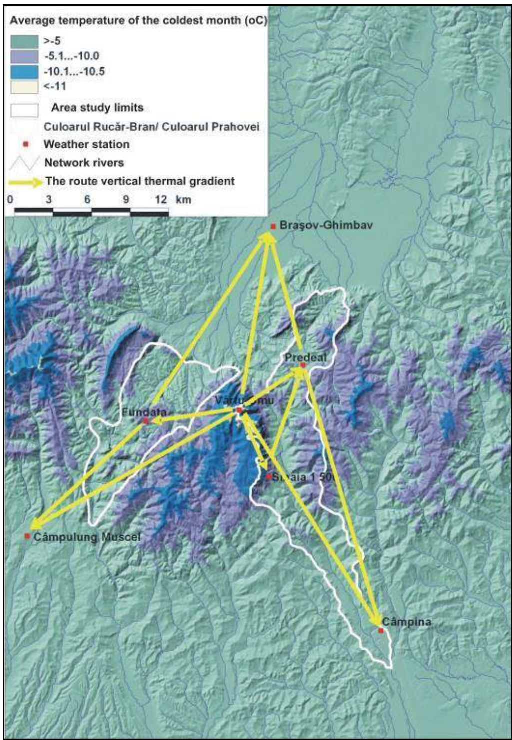

Fig. 9 - The territorial distribution of mean air temperature in thecoldest month of the year and the vertical temperature gradient route

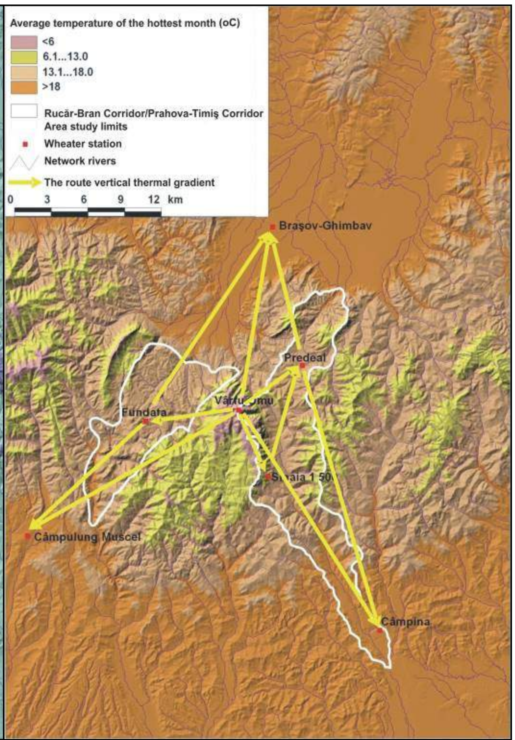

Fig. 10 - The territorial distribution of mean air temperature of the warmest month of the year and the vertical thermal gradients' route

Average annual values of the isotherms decreases as the altitude increase, so most of the two mountain corridors, with altitudes between 800 and 1 600 m, are characterized by values of isotherms between 13º-18ºC.

Then, the values drop further so that isotherms with values between 6º-13ºC are characteristic only for the Carpathian sector of the Prahova-Timiş Corridor and only to very specific areas of Rucăr-Bran. Meanwhile, the high atop of Bucegi Mountains appears to be a real cold climate island, as compared with the sorrounding warmer regions, where isothermal values <6ºC is typical.

3.4. Variability of annual mean air temperature

By reference to the length of data series and to the scale of the entire analysed region, ***the most obvious increases*** (>99% significance level) were recorded in Câmpulung Muscel station in the southern extremity of ***Rucăr-Bran Corridor*** but also on it's territory, at Fundata station (>95% significance level), where the variation rate of average annual temperatures range between +0.78°C/ year, respectively +0.65°C/year (Table 2).

Compared to this region, located west of the Bucegi Mountains, ***in the Carpathian sector of the Prahova Corridor***, ***and the surrounding region in the north*** (Braşov Depression), even if the average annual temperatures are increasing, ***the trends indicate an insignificant increase*** (Omu Peak, Sinaia 1500, Predeal and Braşov-Ghimbav). For these four meteorological stations, the variation rates of annual average temperatures range between +0.29°C/year (Predeal) +0.41...+0.42°C/year (Omu Peak and Braşov-Ghimbav) and can reach up to +0.49°C/year Sinaia 1500. According to the non-parametric Mann-Kendall test it was established as representativity threshold from statistical standpoint, a significance level ≥90%, so that, ***in the Prahova-Timis corridor one may note a significant air temperatures increase trend only in its sub-carpathian sector***, ***at Campina station***, where the variation rate of this climatic parameter is +0.56°C/year (Table 2). ***It results that, annually, the most sustained upward trends of the air temperature are specific to the Rucăr-Bran Corridor and Campulung Muscel Depression (located in Muscelele Argeşului)***, ***but also to the sub-carpathian sector of the Prahova-Timiş Corridor.***

Tab. 2 - Trends in averrage annual temperature variation during 1961-2007

Weather station	Annual average (1961-2007)	General variation rate (°C/year)[1]	Floor vegetation
Omu Peak	-2.4°C	0.41 (-)	Alpine
Sinaia 1500	3.8°C	0.49 (-)	Forest
Fundata	4.4°C	0.65 (*)	
Predeal	5.0°C	0.29 (-)	
Câmpulung Muscel	8.1°C	0.78 (**)	
Braşov-Ghimbav	7.6°C	0.42 (-)	
Câmpina	9.0°C	0.56 (+)	

[3] Mann-Kendall Test (Salmi et. al., 2002)

*** α = 0.001 significance level (99.99%); ** α = 0.01 significance level (99%);

* α = 0.05 significance level (95%); + α = 0.1 significance level (90%);

- = no statistical significance.

3.5. Air temperature variability during specific months

Except the coldest month of the year, at altitudes > 2500 m, the air temperature trends by specific month, show the same variation sign (Table 3).

During the coldest month of the year, the variation the positive range of the air temperature is ***insignificant*** in the Prahova-Timis corridor, ***at altitudes >1500 m*** (Sinaia 1500 and Omu Peak); ***less significant for its Subcarpathian sector*** (+2.3ºC/month Câmpina) ***and for Rucăr-Bran Corridor*** (+2.4ºC/month at Fundata), yet ***a significant increase trend*** (≥ +2.5ºC/month) ***in the south and north surrounding region*** (Câmpulung respectively Braşov-Ghimbav stations) and ***also Prahova-Timiş Corridor***, ***at altitudes of about 1 000 m (Predeal)***.

During the warmest month of the year, there is a significant increasing trend of air temperature for all seven analyzed meteorological stations, having a variation rate between +1.8 ... +2.0°C/month, ***more obvious in case of Rucăr-Bran Corridor***, where the variation rate of air temperature reaches up to +2.3°C/month at Fundata. It results that, at the level of the of thermally specific months, the increasing air temperature trends are more pronounced during the warmest months (July/ August); the most affected is Rucăr-Bran Corridor (especially Fundata station). In the coldest months (January/February), the air temperature increase rates are moderate, with statistical significance only at altitudes <1500 m.

Tab. 3 - The variation trends of the air temperature on specific months during 1961-2007

Weather station	The coldest month	Annual average (1961-2007)	Variation rate (°C/month)[1]	The hottest month	Annual average (1961-2007)	Variation rate (°C/month)
Omu Peak	February	-10.6	- 0.2 (-)	August	5.7	+ 2.1 (**)
Sinaia 1500	January	-5.1	+ 1.8 (-)	July	12.8	+ 2.1 (**)
Fundata	January	-5.2	+ 2.4 (+)	July	13.7	+ 2.3 (***)
Predeal	January	-4.8	+ 2.5 (*)	July	14.6	+ 2.0 (**)
Câmpulung Muscel	January	-2.1	+ 2.7 (*)	July	18.1	+ 1.9 (**)
Braşov-Ghimbav	January	-4.3	+ 3.0 (*)	July	18.0	+ 2.0 (**)
Câmpina	January	-1.7	+ 2.3 (+)	July	19.5	+ 1.8 (**)

[3] Mann-Kendall Test (Salmi et. al., 2002)

*** α = 0.001 significance level (99.99%); ** α = 0.01 significance level (99%);

* α = 0.05 significance level (95%); + α = 0.1 significance level (90%);

- = no statistical significance.

Conclusions

If in the regions with altitudes <1 800 m, within both mountain corridors, the thermal conditions are very similar, the specific thermal regime is better highlighted in the regions higher than 1 800 m, where, depending on altitude, differences are landscape more clear.

Emphasizing the thermal regime comparative analysis is meant to highlight not only the similarities and the differences between the two corridors, but also the influence of the thermal regime on the turist activity in their mountain resorts. There are practised many forms of tourism: rural and agrotourism, religious and/or cultural with etno-folk valences, scientific and eco-tourism etc.

The most important remain the mountain tourism, practised mainly in the resorts specially set-up for winter sports on the Prahova Valley: Sinaia, Buşteni, Azuga and Predeal. In the same time, such type of tourism is vulnerable to the climate changes experienced during the last decades on the grounds of general warming of the mountain climate, as the majority of the ski slopes unfold between 800 and 1 500 m altitude (Bogdan, Mic, 2011).

Nevertheless, presently, in both mountain corridors there are favourableclimate conditions for practising all forms of specific tourism: backpacking, rest, game sports, winter sports etc.

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