TEMPERATURE INVERSIONS IN TRANSYLVANIA

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ABSTRACT. – Temperature inversions in Transylvania. This paper is based on meteorological stations data and statistical methods. Daily maximum and minimum temperatures (from the period 2004-2013) were studied from 22 meteorological stations of Transylvania (s.s.). Factor analysis reveals that temperature inversions are present mainly in winter. Two dominant factors were found, the first is the presence of the depressionar areas, and the second the neighbouring with high relief forms. It is remarkable that Târnăveni (523 m altitude) have approximately the same factor loading for these two factors (that can explain why there are frequently higher minimum temperatures compared to nearest station, Târgu Mureş - 308 m). Additional, daily maximum and minimum temperature from the period 1978-2013 were studied as regard Joseni (750 m) and Bucin (1282 m). Half of the cases, minimum temperature in Joseni is lower than in Bucin. There is no significant trend (at 0.05 levels) regarding yearly number of temperature inversion (taking into account maximum and minimum temperatures). Both in case of maximum and minimum temperature of these two stations, in most cases temperature inversions are related to "anticyclone located east of the Carpathian Basin" and "anticyclone located over the Carpathian Basin" (based on Péczely's circulation types). To be mentioned that all minimum temperatures under -25 ºC registered at Joseni in that period, were due to temperature inversions. On 3 February 1996, in Bucin minimum temperature was -6.4 ºC, while in Joseni have been recorded −27.6 ºC.

Keywords: temperature inversions, Transylvania, factor analysis, trend.

1. INTRODUCTION

Temperature inversions appear when temperature increases with altitude. They are developed due to radiative cooling of the surface, subsidence in altitude or passage of a front. This is a relatively frequent phenomenon in Transylvania, especially in winter.

Daily maximum and minimum temperatures (from the period 2004-2013) were studied from the followed meteorological stations of Transylvania (s.s.): (altitudes are shown in parentheses): Alba Iulia (246 m), Bâlea Lac (2055 m), Baraolt (508 m), Batoş (449 m), Boiţa (518 m), Braşov (534 m), Bucin (1282 m), Dumbrăveni (318 m), Făgăraş (428 m), Joseni (750 m), Lăcăuţi (1776 m), Miercurea Ciuc (661), Odorheiu Secuiesc (523 m), Roşia Montană (1196 m), Sărmaşu (399 m), Sebeş (254 m), Sfântu Gheorghe (523 m), Sibiu (443), Târgu Mureş (308 m), Târgu Secuiesc (568 m), Târnăveni (523 m), Toplița (687 m). In

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addition, daily maximum and minimum temperature from the period 1978-2013 were studied as regard Joseni (Giurgeu Depression) and Bucin (Gurghiu Mountains), both located in Eastern Carpathians, 20 km away from each other.

2. FACTOR ANALYSIS

Daily maximum and minimum winter temperatures (from the period 2004-2013) were studied from 22 meteorological stations of Transylvania (s.s.). Factor analysis was made using the PSPP software (http://www.gnu.org/software/pspp). In order to reduce number of factors, Kaiser (1958) criterion was applied (according to this method, contributions of factors are significant if eigenvalues >1). After this, Varimax method was used, the most common orthogonal rotation method.

In case of winter temperatures, two dominant factors were found, which can explain 82.96 % (in case of minimum temperatures) respectively 81.32 % (in case of maximum temperatures) of variance. Factor loadings are presented in Table 1.

Table 1. ***Factor loadings (in case of winter minimum and maximum temperature)***

	Minimum temperatures		Maximum temperatures	
Alba Iulia	**0.86**	0.41	**0.82**	0.30
Bâlea Lac	0.27	**0.90**	0.25	**0.86**
Baraolt	**0.91**	0.32	**0.85**	0.43
Batoș	**0.77**	0.56	**0.73**	0.61
Boița	**0.76**	0.57	**0.79**	0.55
Brașov	**0.89**	0.34	**0.83**	0.45
Bucin	0.46	**0.85**	0.35	**0.90**
Dumbrăveni	**0.86**	0.41	**0.82**	0.49
Făgăraș	**0.90**	0.32	**0.82**	0.51
Joseni	**0.86**	0.35	**0.89**	0.24
Lăcăuți	0.33	**0.91**	0.33	**0.89**
Miercurea Ciuc	**0.87**	0.31	**0.89**	0.19
Odorheiu Secuiesc	**0.84**	0.48	**0.71**	0.64
Roșia Montană	0.37	**0.88**	0.37	**0.87**
Sarmașu	**0.82**	0.49	**0.84**	0.46
Sebesș	**0.87**	0.37	**0.89**	0.33
Sfântu Gheorghe	**0.90**	0.30	**0.82**	0.48
Sibiu	**0.84**	0.44	**0.81**	0.51
Târgu Mureș	**0.86**	0.43	**0.85**	0.44
Târgu Secuiesc	**0.86**	0.37	**0.80**	0.51
Târnăveni	**0.70**	0.65	**0.80**	0.55
Toplița	**0.86**	0.36	**0.89**	0.24

The first factor affects the depression regions, and the second the mountain areas. In case of minimum temperatures, it is remarkable that in case of Târnăveni, these values are very close (0.70 and 0.65). That can explain why there are frequently higher minimum temperatures compared, for example to the Târgu Mureș station. From studied period, in some meteorological stations from Transylvanian Depression (relatively located close to the Târnăveni meteorological station), the number of days with minimum temperatures (in winter) less than

different values are presented in Table 2. In Târnăveni never were measured temperatures under −20 ºC in that period.

Table 2. ***Number of days with minimum temperature less than −10 ºC, -15 ºC and −20 ºC (in winter)***

	Number of days with:		
Meteorological stations:	Tmin < −10 ºC	Tmin < −15 ºC	Tmin < −20 ºC
Târnăveni (523 m)	58	6	0
Târgu Mureş (309 m)	96	36	10
Dumbrăveni (318 m)	122	58	20
Sărmaşu (399 m)	83	28	4

The greatest difference between minimum temperatures registered at Târnăveni and respectively at Târgu Mureş was in 9 February 2005: −11.6 ºC and −22.3 ºC. The Skew-T diagram from Cluj-Napoca (413 m) observations (http://weather.uwyo.edu/upperair/sounding.html) reveals a strong inversion near surface on that day. (Fig.1)

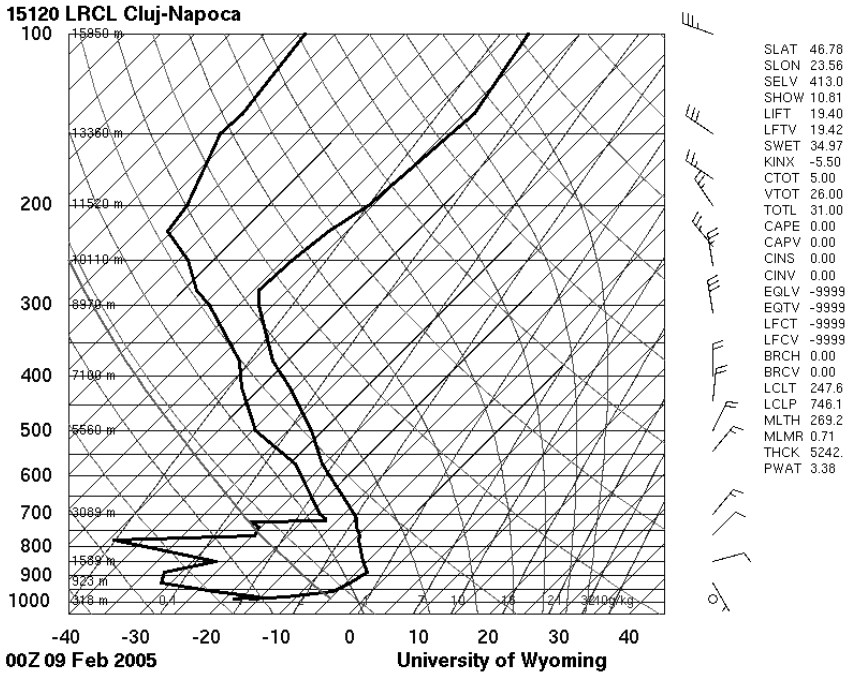

Fig. 1. ***The Skew-T diagram from Cluj-Napoca observations in 9 February 2005 (http://weather.uwyo.edu/upperair/sounding.html)***

In summer, only in case of minimum temperature inversions were evidenced. Two dominant factors were found, which can explain 74.66 % of variance. Factor loadings are presented in Table 3. It is notable that in this case, the

first factor affect especially meteorological stations located in intramountain depressions, and the second factor influences not only the mountain stations, but also some meteorological stations of Transylvania Depression. Factor loading of Târnăveni is very high (0.93), therefore, indicate a strong relationship between the second factor and summer minimum temperatures from this station.

Table 3. ***Factor loadings (in case of summer minimum temperatures)***

	Minimum temperatures	
Alba Iulia	0.62	**0.70**
Bâlea Lac	0.24	**0.93**
Baraolt	**0.88**	0.37
Batoş	0.60	**0.67**
Boiţa	0.39	**0.86**
Braşov	**0.85**	0.36
Bucin	0.43	**0.85**
Dumbrăveni	**0.82**	0.46
Făgăraş	**0.84**	0.38
Joseni	**0.91**	0.22
Lăcăuţi	0.31	**0.89**
Miercurea Ciuc	**0.94**	0.09
Odorheiu Secuiesc	**0.76**	0.59
Roşia Montană	0.05	**0.95**
Sarmaşu	0.51	**0.80**
Sebeşş	**0.74**	0.54
Sfântu Gheorghe	**0.93**	0.21
Sibiu	0.63	**0.66**
Târgu Mureş	**0.69**	0.63
Târgu Secuiesc	**0.86**	0.34
Târnăveni	0.23	**0.93**
Topliţa	**0.88**	0.27

The number of tropical nights (in the period 2004-2013) by far the largest is in Târnăveni (33), followed by Boiţa and Roşia Montană (both with 16). In the rest of stations, this value is below 10. In the case of the mountain and intermountain stations there are not at all tropical nights.

One of the most evident inversion in summer was developed in 30 August 2011, when he highest minimum temperature (of these 22 meteorological stations) was recorded in Târnăveni: 15.5 ºC, while for instance, in Târgu Mureş were measured 7.8 ºC, in Dumbrăveni 6.3 ºC, in Sărmaşu 9.2 ºC, Joseni 3.1 ºC, Miercurea Ciuc 2.2 ºC, Bucin 8.6 ºC, Lăcăuţi 9.1 ºC.

3. TEMPERATURE INVERSIONS IN EASTEARN CARPHATIANS

Daily maximum and minimum temperature from the period 1978-2013 were studied from two meteorological stations: Joseni (Giurgeu Depression), situated at 750 m elevation and Bucin (Gurghiu Mountains), at 1282 m elevation. Both of them are located in the central part of Eastern Carpathians, 20 km away from each other.

As regards maximum temperatures, in 12.2 % of all cases, maximum temperatures in Joseni were lower than in Bucin. Approximately in half of the cases (49.4 %) minimum temperatures in Joseni were lower than in Bucin. In 9.4 % of total cases, both minimum and maximum temperatures were lower in Joseni that in Bucin.

Trend significance was detected using Mann-Kendall test (Mann, 1945; Kendall, 1975) and Makesense soft (Salmi et al., 2002). There is no significant linear trend (at 0.05 levels) regarding yearly number of temperature inversion (taking into account maximum and minimum temperatures). However, the quadratic regression shows that in the case of minimum temperatures, at the beginning of the 90s, there is an increase of the number of days with inversions (fig. 2).

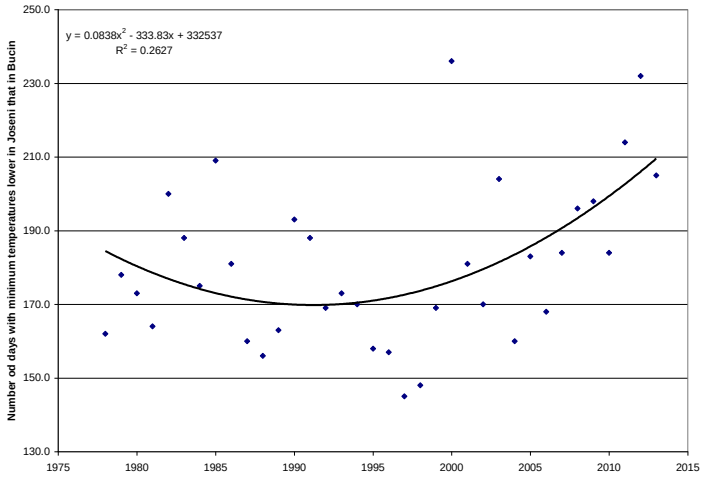

Fig. 2. ***Number of inversions (number of days when minimum temperatures in Joseni are lower than in Bucin) and the quadratic regression line***

In the studied period, minimum temperatures at Joseni were under −25 ºC in 101 times. In all cases, in the same time, at Bucin were registered higher minimum temperatures. Maximum number of days with minimum temperatures under −25 ºC was registered in 1985 (Fig. 3). In Bucin only in 3 cases minimum temperature decreased under −25 ºC.

The largest difference between minimum temperatures was registered on 3 February 1996: in Bucin minimum temperature was −6.4 ºC, while in Joseni have been recorded −27.6 º. (On this day maximum temperature at Bucin was +4.0 ºC, while in Joseni −9.9 ºC).

In the period 11-22 January 1985 not only the minimum temperatures were lower in Joseni than in Bucin, but also temperatures at main synoptic hours (00, 06, 12, 18 UTC) (Fig. 4). In all that time, at Joseni calm wind was characteristic, fog

and mist was present (Fig. 5). The absolute minimum temperature in the studied period from Joseni was recorded in 14.01.1985: −34.8 ºC.

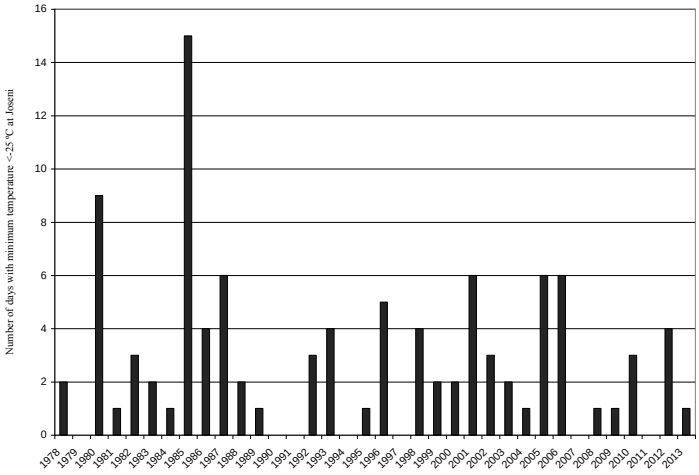

Fig. 3. ***Number of days with minimum temperatures < −25 ºC at Joseni***

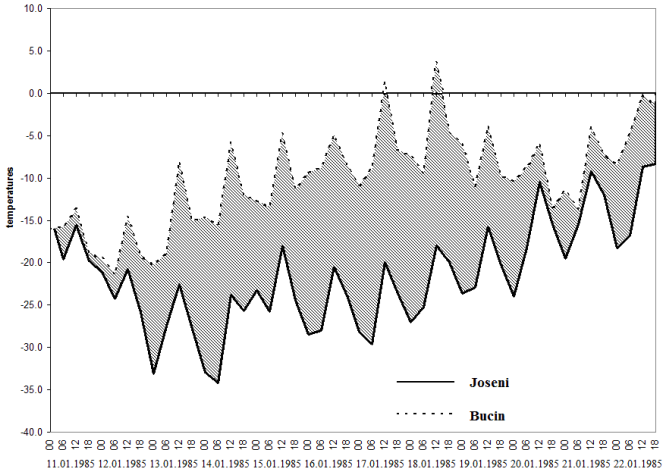

Fig. 4. ***Temperatures at main synoptic hours in period 11-22 January 1985. The shaded area represents thermic inversion.***

In the period 1978-2002, based on Péczely's circulation types (who defined 13 large-scale weather situations in Carpathian Basin) (Péczely, 1983; Károssy, 2004) both in case of maximum and minimum temperatures of these two stations, in most cases temperature inversions are related to "anticyclone located east of the Carpathian Basin" and "anticyclone located over the Carpathian Basin". (http://cost733.geo.uni-augsburg.de/cost733cat-1.2/PECZELY). The results of the analisys between temperatures from Joseni and Bucin are presented in Table 4.

Fig. 5. ***A rather common situation: fog in Joseni, sunshine in Bucin.***

Table 4. ***Thermal inversions in the Giurgeu Depression (relative frequencies, expressed in percent) and related Péczely's circulation types (period 1978-2002). The most frequent cases are marked with bold.***

	Inversions (relative frequencies, %) based on:	
Péczely's circulation types:	Maximum temperature	Minimum temperature
Cold front with meridional flow	4.2	9.9
Anticyclone over the British Isles	3.3	5.0
Cold front arising from a Mediterranean cyclone Meridional, southern types	1.6	1.7
Warm front arising from a meridional cyclone	7.7	6.7
Anticyclone located east of the Carpathian Basin	**28.8**	**19.1**
Warm front arising from a Mediterranean cyclone Zonal, western types	12.2	7.4
Zonal cyclone	1.6	2.7
Anticyclone located west of the Carpathian Basin	6.0	11.0
Anticyclone located south of the Carpathian Basin Zonal, eastern types	6.5	6.1
Anticyclone located north of the Carpathian Basin	6.6	8.9
Anticyclone located over the Scandinavian Peninsula, Central types	1.6	3.4
Anticyclone located over the Carpathian Basin	**18.2**	**14.3**
Cyclone located above the Carpathian Basin	1.6	3.5

4. CONCLUSIONS

Daily maximum and minimum temperatures (from the period 2004-2013) were studied from 22 meteorological stations of Transylvania (s.s.). Factor analysis reveals that temperature inversions are present mainly in winter. Two dominant factors were found in the case of winter maximum and minimum temperatures and in case of summer minimum temperatures. Generally, the first affect mountain areas and the second the depression regions. Factor analysis highlights the importance of the elevation of stations. The Târnăveni meteorological station is located at 523 m elevation, and often has a behavior as a mountain in terms of temperature inversions. While Târnăveni town is under 300 m elevation. That can explain why there are frequently higher minimum temperatures compared to nearly station, Târgu Mureş – 308 m or why here number of tropical days are greatest. Daily maximum and minimum temperature from the period 1978-2013 were studied as regard Joseni (750 m) and Bucin (1282 m). Half of the cases, minimum temperature in Joseni is lower than in Bucin. There is no significant trend (at 0.05 levels) regarding yearly number of temperature inversion (taking into account maximum and minimum temperatures). In most cases temperature inversions are related to "anticyclone located east of the Carpathian Basin" and "anticyclone located over the Carpathian Basin" (based on Péczely's circulation types). To be mentioned that all minimum temperatures under -25 ºC registered at Joseni in that period (in number 101), were due to temperature inversions. Likewise, the absolute minimum temperature from 14 January 1985, when in Joseni were measured −34.8 ºC, and in Bucin −15.6 ºC. On 3 February 1996, in Bucin minimum temperature was −6.4 ºC, while in Joseni have been recorded −27.6 ºC.

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