Comparative study of air temperature evolution in the Ciuc depression

[1,2]Sándor Petres, [2]Réka Boga, [3]Ágnes Keresztesi, [4]Gina Ghita, [4]Mihaela Ilie, [4]György Deák

[1] University Politehnica of Bucharest, Bucharest, Romania; [2] University Sapientia, Miercurea-Ciuc, Romania; [3] Babeș-Bolyai University, Cluj-Napoca, Romania; [4] National Institute for Research and Development in Environmenal Protection, Bucharest, Romania. Corresponding author: S. Petres, spetres@freemail.hu

Abstract. The goal of this paper is to present an analysis of evolution in time and trends of air temperature, and the number of days with significant characteristics of the air temperature, in the city of Miercurea-Ciuc (Romania) for the 2006-2015 timeframe. The data were measured at an hourly basis by the Miercurea-Ciuc weather station, situated at an altitude of 661 m, belonging to the National Administration for Meteorology. The results were compared with data presented in relevant studies referring to temperature measurements for the last century. The provided results were summarized, processed and discussed, the main conclusion being that the annual average of air temperature is continuously increasing over the last decade, due to global and local factors, the changes affecting even the four-season type moderate continental climate established in the region.
Key Words: air temperature, closed basin, amplitudes, significant temperature characteristics.

Introduction. The issue of tendencies in air temperature evolution was addressed as early as the 19th century (Heller 1888). After 1990, amidst the growing concern regarding changes in the global climate, and due to the revolutionary development of scientific and communication methods, more and more studies concerning temperature variations and global tendencies became available (Machidon et al 2012; WMO 2016). The National Administration for Meteorology also assesses the evolution of the climate of Romania, through looking on the territorial distribution and time evolution of air temperature (Climate of Romania 2008).

Anthropic interventions in the last decades resulted in drastic changes of the climate of depression areas (Korodi et al 2017). Massive deforestation and watercourse regulation led to significant decrease of evapotranspiration, drainage of floodplains and loss of peat soils. These are just some of the aggressive interventions that, unfortunately, are going on even nowadays, and cause notable consequences such as extreme weather. Intermontane depressions are closed or semi-enclosed basins, where the contribution of evapotranspiration from local sources to the water cycle is vital. Decreasing evapotranspiration leads to increased static stability of the lower layers of the atmosphere, thus to the occurrence of intense thermic inversion periods (Bogdan & Niculescu 2004; Szép & Mátyás 2014; Szép et al 2016a, 2016b). Due to these thermic inversions and stable atmospheric conditions, pollutant dilution processes are limited, leading to their accumulation, especially in the cold period (Szép et al 2016a, 2017a, b).

The present paper is a comparative study of key temperature values for the 1960-1990 and 2006-2015 periods, through which we identified the above-mentioned aspects. The results will lay ground for the research of thermic inversion phenomena and the interacting pollution episodes, of the alteration of climate factors and induced socio-economic risks. The ultimate objective of this process is to project and implement strategies which can lead to a better quality of life in the region.

Material and Method

Study area. The Ciuc Depression is a closed basin situated mostly in the shelter of the orographic dam determined by the surrounding mountain frame of the Eastern Carpathians (Figure 1), on the upper course of the river Olt, at an altitude of 600-700 m.

Figure 1. Miercurea-Ciuc, Ciuc Depression, Eastern Carpathians (Map source: www.openstreetmap.org)

The morphological characteristics determine the specificity of the climate of the basin (Apăvăloae et al 1990). Because of the relatively closed, bowl form of Ciuc depression the presence of microclimate can be observed (Szép et al 2016c). From climatic point of view, the depression floor is the land of thermic inversions, of the lowest temperatures in the country, determining early and late frosts, recurrent radiation fogs and a high frequency of calm atmosphere (Bogdan & Niculescu 2004). The perpendicular orographic dam is affecting the circulation of cyclones, thus accentuating these particularities (Tamás 1997). Appearance of fog and thermic inversions is common in wintertime (Kristó 1994). In the Ciuc Depression, average temperature is only 0.2 centigrade lower than for the surrounding 1800-1900 m peaks, but 1-2 grades lower as on the 1200-1400 m, warmer hillsides (Szép & Mátyás 2014). A very intense, 5-600 m thick thermic inversion layer can fill the whole topoclimatic space, and it can expand up to 1200 m in the case of invasion of polar air, determined by the Eastern European anticyclone (Bogdan & Niculescu 2004). The main wind direction is westerly and north-westerly (Kristó 1994).

The ground-based automatic weather station of Miercurea-Ciuc (661 m) is operated by the National Administration for Meteorology of Romania. The air temperature was sampled with an hourly time resolution by a TS Thermometer sensor with measuring range between -40^{o}C and +50^{o}C installed at 2 m meter above the ground. Regarding data processing we have used values validated by the National Administration for Meteorology.

Results and Discussion

The diurnal profile of air temperature. Theoretically, the diurnal profile of air temperature presents a simple variation, with a maximum value reached between 2-3 o'clock in the afternoon and a minimum value just before sunrise (Pop 1988). Figure 2 shows the diurnal profile of minimum, maximum and average temperatures for the 2006-2015 period. There is a good correlation with the theory, the only difference being the timeframe for the maximum temperature, which shifts to 1-2 o'clock in the afternoon.

The minimum value for the amplitude of daily temperature variations is 0.7°C, the maximum value 28.4°C, the average daily variation is 13.04°C.

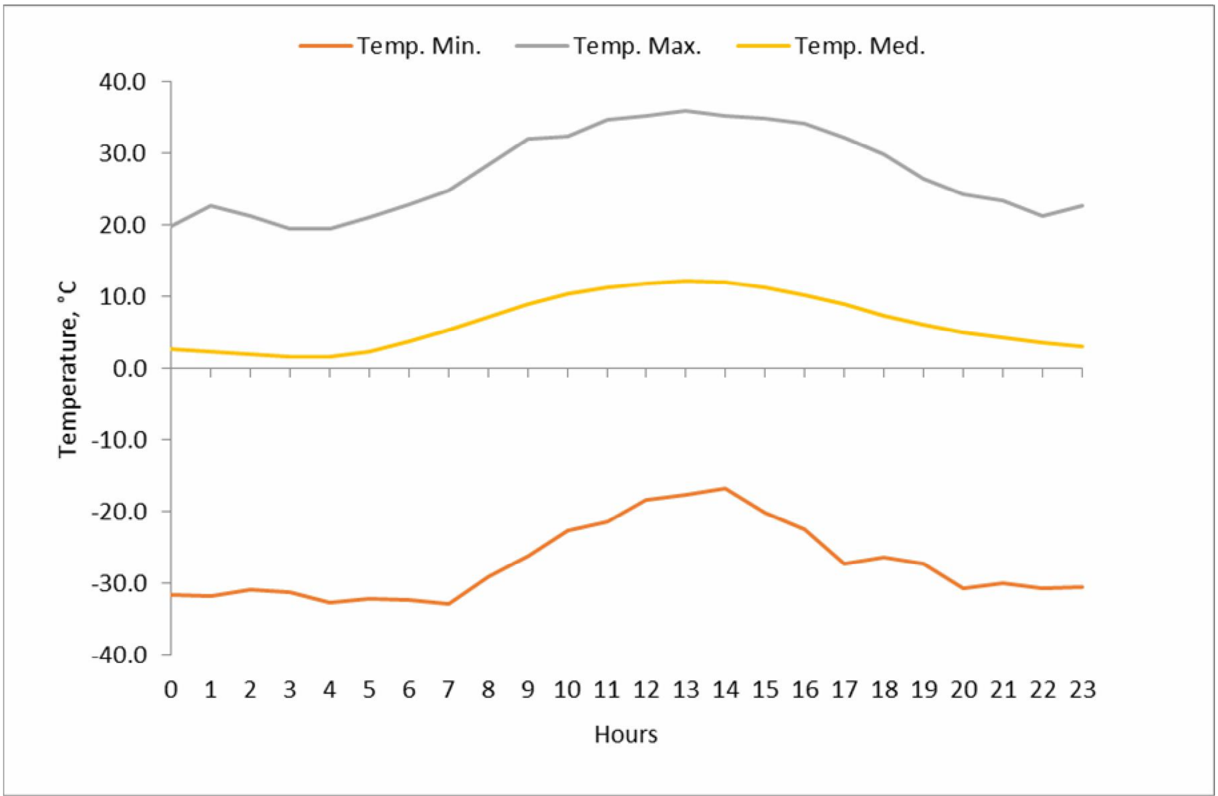

Figure 2. Diurnal air temperature profile (minimum, maximum, average) at Miercurea-Ciuc.

Yearly average of temperature. In Ciuc Depression, the depression floor is bounded by the 6°C isotherms, with lower internal values caused by thermic inversions (Bogdan & Niculescu 2004). The average temperature for the 1960-1990 period was 5.5°C (Bogdan & Niculescu 2004), and even lower, 5.2°C for the 1983-1992 decade (Tamás 1997). There is a significant increase, of 1°C for the 2006-2015 period, almost all of the yearly averages being higher than 6.2°C, in two of the cases they even exceeded 7°C. This difference correlates well with the values of global warming for the same timeframe (WMO 2016). Figure 3 shows the evolution of yearly average values, with an obviously ascending trend.

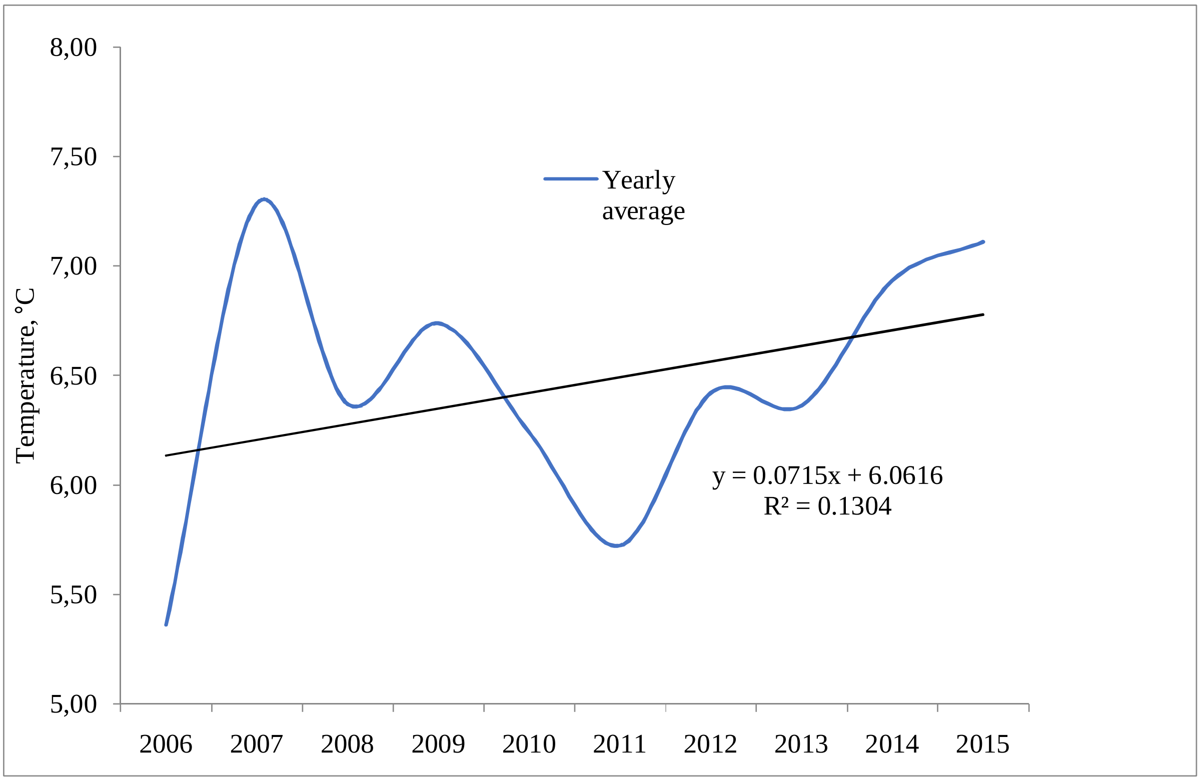

Figure 3. Yearly average values and trend for air temperature between 2006 and 2015 (°C).

Monthly averages of air temperature. During the year, monthly average is heavily fluctuating, in strong concordance with the variation of the radiative-caloric balance, the influence of the configuration of the basin and of the massive orographic dam, which attenuates the impact of external air masses pumped into Romania by baric centers. Consequently, we have low temperature values during winter, similar to the 1700-1800 m mountain peaks, and moderate values during summer (Bogdan & Niculescu 2004).

Figure 4 presents a comparison of the monthly average values for the 1960-1990 and 2006-2015 periods. The highest differences are for January, July and August, so we found significant growth in temperature for the coldest and the warmest months. January has even been warmer than February four years out of ten.

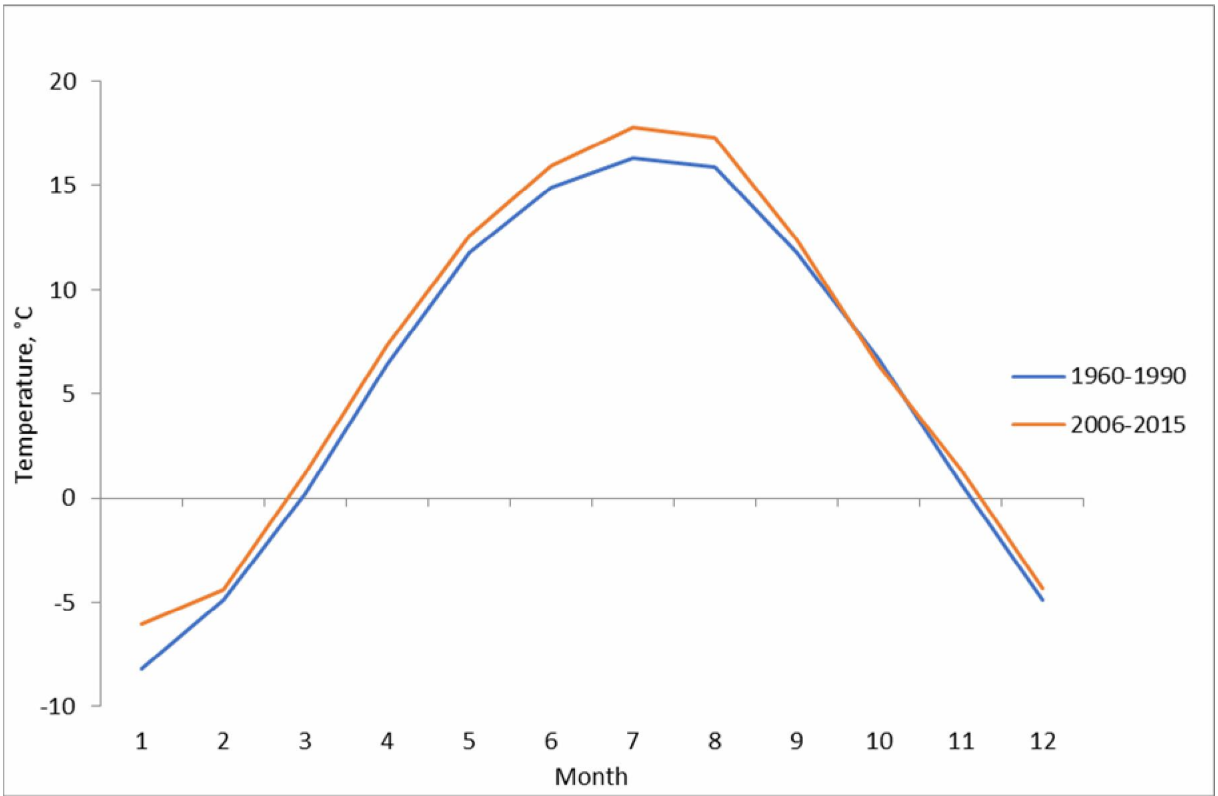

Figure 4. Monthly average air temperature values for 1960-1990 and 2006-2015 (°C)

Monthly and yearly average values for the 2006-2015 timeframe are presented in Table 1. Starting from January, the coldest month of the year, air temperature starts to rise (slowly in February faster in the spring) till July, the warmest month. Temperature fall is slow at the end of summer but increases during autumn. The biggest positive jump occurs in April (6.1°C), the biggest negative jump in October (-6.0°C).

The coldest month is January, followed very closely by February. July is the warmest month, but August is almost as warm, just like in the high mountain area (Bogdan & Niculescu 2004).

Winter is a relatively long season. Negative mean temperatures can appear from November, but not later than December (-4.3°C), the lowest value being reached in January (-6.1°C). From February, monthly average starts to heighten (-4.4°C), becoming positive from March or April till October or November. The monthly average reaches its peak value in July, 17.8°C.

Table 1

Monthly and yearly average air temperature for the 2006-2015 decade (°C)

Year	*I*	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VIII*	*IX*	*X*	*XI*	*XII*	*Y*
2006	-12.9	-7.3	-0.7	7.7	11.2	14.9	16.8	16.0	12.4	6.7	1.5	-2.1	5.4
2007	0.8	-0.4	3.6	6.2	14.3	16.8	18.8	17.8	10.6	6.6	-1.0	-6.5	7.3
2008	-7.5	-1.9	3.1	7.7	11.8	16.0	16.7	17.5	11.0	7.1	0.0	-5.1	6.4
2009	-6.9	-2.3	0.9	7.7	12.2	16.0	17.5	16.4	12.5	7.1	2.9	-3.1	6.7
2010	-7.5	-4.0	0.1	7.0	13.0	16.4	17.7	18.3	11.8	3.9	4.1	-5.9	6.2
2011	-6.2	-5.1	0.3	6.2	11.7	15.6	17.1	16.5	13.5	4.2	-3.2	-1.9	5.7
2012	-5.1	-10.0	-1.5	8.3	13.4	17.7	20.3	17.9	14.5	8.0	1.1	-7.6	6.4
2013	-7.3	-3.0	-0.8	8.7	13.6	16.2	17.0	17.9	10.9	6.3	3.8	-6.9	6.4
2014	-3.2	-4.3	4.7	7.8	11.5	14.3	17.6	16.7	12.3	7.6	1.0	-2.7	6.9
2015	-4.8	-5.5	2.3	6.1	12.9	15.5	18.6	17.6	14.4	6.2	3.5	-1.4	7.1
Mean	-6.1	-4.4	1.2	7.3	12.5	15.9	17.8	17.3	12.4	6.4	1.4	-4.3	6.5

Y - year average.

Average monthly and annual amplitude of temperature variations. Thermic contrast between winter and summer is highlighted by the average annual amplitude. In the Ciuc Depression, the average annual amplitude is higher than 24°C, being 24.5°C for Miercurea-Ciuc (Bogdan & Niculescu 2004). Table 2 shows minimum, maximum and mean monthly amplitudes for the 2006-2015 timeframe. There is an accentuated growth in amplitudes, the average monthly amplitude for the decade being 5.2°C higher than the average for 1960-1990.

Table 2

Minimum, maximum and mean monthly amplitudes of air temperature variations for the 2006-2015 period (°C)

Amplitude	*I*	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VIII*	*IX*	*X*	*XI*	*XII*	*Y*
Minimum	26.7	24.4	25.1	23.0	24.2	24.1	23.3	26.3	22.8	24.6	24.4	23.1	24.3
Maximum	39.7	38.8	43.2	33.7	34.1	30.2	31.7	34.9	35.1	37.0	33.1	36.0	35.6
Mean	32.6	32.5	32.8	27.2	29.2	27.1	27.4	29.0	28.5	31.1	28.5	30.1	29.7

Absolute minimum temperature. The Ciuc Depression is one of the closed Carpathian basins with the lowest temperature values and the most intense thermic inversions, due to the attenuated flux of radiation and the compact orographic dam which facilitates a better sedimentation of cold air at the depression floor under anticyclonic circumstances (Szép et al 2016d). The absolute minimum air temperature in the Ciuc Depression went below -38°C, the value -38,4°C measured on 14.01.1985 being just 0.1°C higher than the absolute minimum for Romania, recorded at Bod, -38.5°C on 25.01.1942 (Bogdan & Niculescu 2004). The minimum value for the 2006-2015 timeframe was -32.8°C (26.01.2006).

If the annual minimum temperature values registered before 1980 were below -20°C almost every year, half of them being even below -30°C (Călinescu & Tepeș 1979), for the 2006-2015 decade we found that all annual minimum values were also below -20°C, but they went below -30°C just in 2006 (in January and February) and 2010 (in January). The results are in line with the increasing tendency observed for average temperatures.

During the 1960-1990 period, monthly absolute minimum temperature values were negative for almost all months excepting July. From September till March, minimum values could fall below -20°C, and even below -30°C from December till February (Bogdan & Niculescu 2004). However, in the 2006-2015 timeframe, minimum values were constantly negative only from September till April, the months of May (three times) and June (seven times) were partially free, and the months of July and August totally free of negative temperatures.

Absolute maximum temperature. The dominant character of basinal relief, with accentuated calm of the atmosphere and temperature inversions, has some influence on the absolute maximum temperature values (Petres et al 2017). Although they can exceed 35°C on the depression floor, the occurrence frequency of such values is limited. During the 1960-1990 period, the maximum monthly values for temperature were always positive, in wintertime and in summer. Though temperatures above 30°C could have occurred from April till September, values above 35°C were only registered in July. The absolute maximum for air temperature, 35.5°C, was measured at Miercurea-Ciuc on 30.07.1953 (Bogdan & Niculescu 2004).

During the 2006-2015 decade, all monthly maximums were positive, the values possibly exceeding 20°C from March till November, and values beyond 30°C possibly occurring from May till September. On 26-27.08.2012, there were above 35°C, the absolute maximum air temperature at Miercurea-Ciuc reaching a new record (35.9°C, 26.08.2012).

The amplitude of temperature variations. At Miercurea-Ciuc, the absolute amplitude of temperature variation is 74.3°C. Annual amplitudes for the 2006-2015 period were between 54.9°C and 65.2°C, with an average value of 59.7°C.

Days with significant temperature characteristics. The specific climate of the depression is highlighted by the occurrence frequency of days with significant characteristics of air temperature, affecting air quality in many ways. The values of these extreme temperature indices for the 2006-2015 period are shown in Table 3.

Table 3

The number of days with different significant characteristics of temperature between years 2006 and 2015

Year	*Frosty nights*	*Winter days*	*Cold days*	*Summer days*	*Tropical days*
2006	51	67	169	41	3
2007	28	29	167	54	15
2008	50	51	162	51	10
2009	35	44	163	49	3
2010	50	56	168	49	9
2011	57	58	190	50	1
2012	71	73	171	91	36
2013	59	51	168	50	6
2014	26	38	156	46	3
2015	30	35	161	71	19
Average	46	50	168	55	11

The intensity of the cooling process during the cold season. This process is marked by the frequency of the days when the minimum, average and maximum temperatures drop below -10°C and 0°C respectively (Bogdan & Niculescu 2004).

Frosty nights. The annual mean occurrence frequency of the days when the minimum value of air temperature falls below -10°C (frosty nights) is around 46. The interim period is affected by these heavy frosts is November-March. The maximum number of frosty nights within a month is recorded in January (an average of 14 cases), the average numbers observed in February and December being close to that (12 and 11 respectively). The months of November and March can present frosty nights (3-5 days in average). Sometimes, such cases occurred even in October (in 2006 and 2011). One can find a high fluctuation of the numbers recorded.

Winter days. Comparing to other specific parameters of the cold season, the occurrence frequency of these days is slightly lower. The annual mean number of winter days is 50. During the year, the time interval when the maximum daily temperature can drop below 0°C has been reduced from October-April (till 1990) to November-March. The maximum monthly number of cases (17 in average) is observed in December and January. In February, this number decreases to 11. At the beginning and at the end of the interval when winter days can occur, their monthly average frequency is 2-3 cases.

Cold days. The occurrence frequency of these days marks the intensity of the cooling process. The annual average number of the days when the minimum temperature is situated below 0°C is around 168, clearly higher than the average (160) for the 1960-1990 timeframe (Bogdan & Niculescu 2004), but much lower than the mean value (210-220) for the 1983-1992 period Tamás 1997. The time interval of the year when cold days can appear is September-May. There were two years when such cases were recorded in June. However, the daily minimum of air temperature did not fall below 0°C in July and August. The highest number of cold days occurred in December and January, when the minimum of the air temperature falls to negative values for 29-30 days (so for the entire month). A high number of cold days, 23-27, are recorded in November, February and

March. At the beginning of the vegetation period, the average frequency of cold days is 14 in April and 3 in May.

The intensity of the warming process during the hot season. The particularities of this depression area enclosed in a mountain region affect the intensity of the warming process during the hot season, reducing it to moderate or even weak. Nevertheless, the advection of warm continental air, and even more local warming processes, can lead to maximum air temperatures increasing above 25°C (summer days) or further above 30°C (tropical days). There is an obvious moderating role of the mountain in the warming process (Bogdan & Niculescu 2004).

Summer days. The maximum value of air temperature raises above 25°C for an average of 55 days per year, which is clearly higher than the average of 45-50 days recorded before 1990. The possibility of the first appearance of summer days shifted to April, an average of 4 days being observed for the month of May. From June, as solar radiation level become higher, the number of cases increases to 11, and in July and August reaches the average maximum of 17-18 days, higher than in the last century (14-15 days). The number of summer days decreases sharply during September, to an average of 5 cases. There is still possible to have summer days in October, but the average frequency of occurrence is below 1.

Tropical days. Sometimes, waves of hot air can reach the Ciuc Depression, but, due to the moderating role of the surrounding mountains, the frequency of tropical days is very low. However, their average number (11) during the 2006-2015 decade is noticeably higher than in the last century (3-4 cases per year). As for all the other categories of days with significant temperature characteristics, one can observe very high fluctuations for the monthly and annual values.

Conclusions. The calculations made for the hourly results of temperature measurements for Miercurea-Ciuc indicates an accentuated growth of annual average values, the difference between the average of the 2006-2015 decade and the mean value for the 1960-1990 period correlates well with the value of the average global warming during the same time interval. For average monthly temperatures, the highest differences between the two compared periods were found for the coldest (January) and the hottest months (July and August) of the year, and are above 1°C.

The yearly average of the mean monthly amplitudes has greatly increased, while the number of months and years with minimum temperatures below -30°C, as well as time intervals with negative minimum temperatures decreased. The record set in the last century for the absolute maximum value of air temperature at Miercurea-Ciuc got broken, the new absolute maximum value being 35.9°C.

The intensity of the cooling processes decreased, the one of the warming processes increased, the most spectacular difference observed is the much higher occurrence frequency of tropical days. Along with the warming course, one can observe the accentuated fluctuation of the occurrence frequency of the days with significant characteristics of temperature, as well as the alteration of the type of the local climate, the four-season characteristic transforming in a two-season type of climate.

Acknowledgements. We are grateful for the support of the National Administration for Meteorology for the meteorological data.

References

Apăvăloae M., Apostol L., Pîrvulescu I., 1988 [Characteristics of thermic inversions in the Ciuc Depression]. Lucr. Semin. Geogr. „Dimitrie Cantemir”, Romania, 9:111-118. [in Romanian]

Bogdan O., Niculescu E., 2004 Specific climatic aspects of Giurgeu, Ciuc and Braşov depressions. Pedogenetic factors and processes in the temperate climatic zone, New series, Romania 2:3-115.
Călinescu G., Tepeş E., 1979 [Giurgeu and Ciuc depressions – the "pole of cold" of our country]. Studii şi Cercetari, partea I-a, Meteorologie, IMH, Romania, pp. 435-441. [in Romanian]
Heller Á., 1888 Az időjárás. Természettudományi Könyvkiadó-Vállalat & Magyar Tudományos Akadémia, Hungary, pp. 1-174
Korodi A., Petres S., Keresztesi Á., Szép R., 2017 Sustainable development. Theory or practice? Applied and Environmental Geophysics. Accepted manuscript, SGEM17/C/17775/31.03.2017.
Kristó A., 1994 [Environmental assessment and pollution sources of the Csík-basins]. Csíki Zöld Füzetek 1:7-26. [in Hungarian]
Machidon O., Apostol L., Machidon D., Buruiana D., 2012 Study of the evolution of the air temperature in Moldavia Region (Romania) over the last 76 years. Annuals of DAAAM for 2012 & Proceedings of the 23rd International DAAAM Symposium, DAAAM International, Austria 23(1):0689-0692.
Petres S., Korodi A., Keresztes R., Szép R., 2017 Tendencies and particularities in thermic inversion episodes in the Ciuc Basin – Eastern Carpathians, Romania. Applied and Environmental Geophysics, Accepted manuscript.
Pop G., 1988 [Introduction in meteorology and climatology]. Edit. Ştiin. Enciclop., Romania, 343 pp. [in Romanian]
Szép R., Mátyás L., 2014 The role of atmospheric stability in high-PM10 concentration episodes in Miercurea-Ciuc (Harghita). Carpathian Journal of Earth and Environmental Sciences 9:241-250.
Szép R., Keresztes R., Constantin L., 2016a Multi-model assessment of tropospheric ozone pollution indices of risk to human health and crops, and ozone deposition in Ciuc Depression – Romania. Revista de Chimie 67(3):408-413.
Szép R., Keresztes R., Deák G., Tobă F., Ghimpusian M., 2016b The dry deposition of PM10 és PM2.5 to the vegetation és its health effect in the Ciuc basin. Revista de Chimie 67(4):639-644.
Szép R., Keresztes R., Korodi A., Tonk S., Niculae A. G., Birloiu A. M., 2016c Dew point – indirect particulate matter pollution indicator in the Ciuc basin – Harghita, Romania. Revista de Chimie 67(10):1914-1921.
Szép R., Mátyás L., Keresztes R., Ghimpusan M., 2016d Tropospheric ozone concentrations - seasonal and daily analysis and its association with NO and NO2 as a function of NOx in Ciuc Depression – Romania. Revista de Chimie 67(2):205-213.
Szép R., Keresztes R., Korodi A., Tonk S., 2017a The examination of the effects of relative humidity on the changes of tropospheric ozone concentrations under environmental circumstances in the Ciuc basin, Romania. Revista de Chimie, Accepted manuscript.
Szép R., Keresztes R., Korodi A., Tonk S., 2017a Study of air pollution and atmospheric stability in Ciuc basin – Romania. Revista de Chimie, Accepted manuscript.
Tamás L., 1997 Miercurea-Ciuc – geography of population and settlements (Csíkszereda népesség-és településföldrajza). MSc Thesis, Janus Pannonius University Pécs, Hungary, pp. 2-9.
WMO, 2016 Provisional WMO Statement on the Status of the Global Climate. Available at: https://public.wmo.int/en/media/press-release/provisional-wmo-statement-status-of-global-climate-2016. Accessed: November, 2016.
*** 2008 Climate of Romania, Editura Academiei Române, ISBN 978-973-27-1674-8, National Administration for Meteorology, Romania.
*** www.openstreetmap.org.

Received: 27 May 2017. Accepted: 21 June 2017. Published online: 30 June 2017.
Authors:
Sándor Petres, Sapientia Hungarian University of Transylvania, Faculty of Technical and Social Sciences, Piaţa Libertăţii no. 1, 530104, Miercurea Ciuc, Romania; Politehnica University of Bucharest, Department of Analytical Chemistry and Environmental Engineering, Gheorghe Polizu 1-7, 011061, Bucharest, Romania, e-mail: spetres@freemail.hu
Réka Boga, Sapientia Hungarian University of Transylvania, Faculty of Technical and Social Sciences, Piaţa Libertăţii no. 1, 530104, Miercurea Ciuc, Romania, e-mail: keresztes91@gmail.com
Ágnes Keresztesi, Babeș-Bolyai University, Institute for Doctoral Studies, Environmental Doctoral School, Fântânele 30, 400294, Cluj-Napoca, Romania, e-mail: keresztesiagi@gmail.com
Gina Ghita, National institute for Research and Development in Environmenal Protection, 294 Splaiul Independenţei, 6th District, 060031, Bucharest, Romania, e-mail: gina.ghita@incdpm.ro
Mihaela Ilie, National institute for Research and Development in Environmenal Protection, 294 Splaiul Independenţei, 6th District, 060031, Bucharest, Romania, e-mail: mihaela.ilie@incdpm.ro
György Deák, National institute for Research and Development in Environmenal Protection, 294 Splaiul Independenţei, 6th District, 060031, Bucharest, Romania, e-mail: dkrcontrol@yahoo.com

How to cite this article:
Petres S., Boga R., Keresztesi A., Ghita G., Ilie M., Deák G., 2017 Comparative study of air temperature evolution in the Ciuc depression. Ecoterra 14(2):60-69.