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THE THERMAL REGIME OF AIR IN THE RARĂU MASSIF

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Key words: air thermal regime, Rarău Massif

Abstract. The air temperature variability and locally global warming impact, in the North Eastern Carpathians, have analyzed, namely in the high area of the Massif Rarău, as the environmental implications of these changes. Also taking into account the touristic potential of this area, some aspects of thermal regime change have been highlighted, with implications for tourism. For this study the string climate data have been used from the meteorological station Rarău, currently belonging to the Faculty of Geography and Geology, University Alexandru Ioan Cuza.. The yearly average of air temperature at the meteorological station Rarău was 2.5^{o}C over the period 1958-2015. The annual variations were from -1.3^{o}C in comparition with the annual average in 1980 to +1.7^{o}C in 2015. The lowest monthly average was in January, 6.7^{o}C, the highest in July, 11.8^{o}C and annual average amplitude was 18.5^{o}C.

Introduction

The Rarău Massif is located in the central group of the Eastern Carpathians, it has maximum altitude of 1651 m and 600 m minimum altitude in the valley of Moldova river. The massive is situated in the transitional temperate climate, in the sector with aridity influence, woodly district, climatic level of the medium and small mountains (Geography of Romania vol. 1, 1983). From East, the studied area receives frequently polar continental air masses, cold and dry in the winter (which often stop in the Moldova Valley, generating frequent and intense thermal inversions). The valleys of Moldova and Bistrița river favorize also, low thermal inversions in the second part of nights and in the early morning especially in the in the clear sky or anticyclonic periods. In summer, from the East, advection of warm and dry air have been appear. From the West, over Bârgău Mountains, Depression of Dorna and Giumalău, Rarău Mountains, Moldova Valley and Bistrița Valley usually receive old polar maritime air masses. When crossing Giumalău and

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Mestecăniș mountains, sometimes occurs foehn. Along Bistrița and Moldova valleys, in the winter, cold air masses penetrate sometimes from high altitude Dorna Depression, producing thermal inversions (Apostol, Rusu, 1988; Rusu, 2002).

Materials and methods

For this work meteorological data from the meteorological station Rarău, from 1958 to 2004 (TM1, TM 11) and meteorological observation records for 2005-2015 and synoptic maps for specific periods have been used.

Results

The average annual air temperature. At the meteorological station Rarău the annual average from 1958 to 2015 was 2.5°C. Annual averages higher than the annual average have been appeared in 45% of years, which show similar weights of cold and warm years and positive or negative differences, from the annual average. The highest annual average was recorded in 2014, 4.4°C, and the lowest in 1980, with the value of 1.2°C. The difference between the extreme values shows a normal annual thermal variability for this period of 58 years. The annual averages values were lower than the annual averages which were recorded in a total of 30 years. In 1967 and 2000, the annual average value was equal to the annual average, these two years representing 4% of cases. Sliding averages for the periods of 10 years, show a decrease in temperature until the years 1985-1987 and slow growth until 2006, then strong growth until 2015. (Fig. 1).

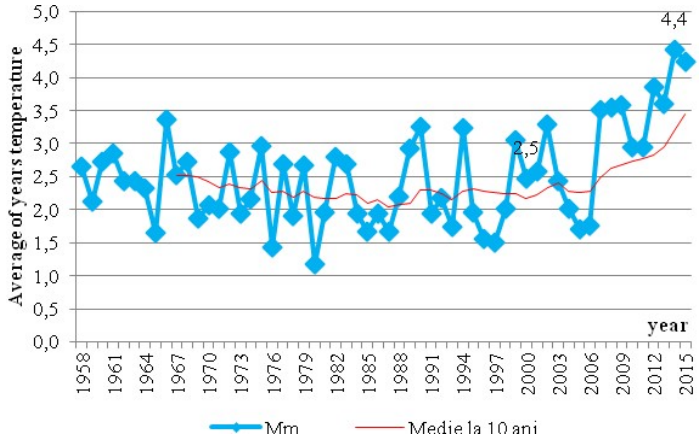

Fig. 1. The evolution of the average monthly of air temperature at Rarau station from 1958 to 2015

The lowest monthly average was recorded in January, -6.7° C, the highest monthly average in July, 11.8° C and the average annual amplitude was 18.5° C, normal to this altitude, high-altitude climate receiving well the ocean influences (fig. 2)

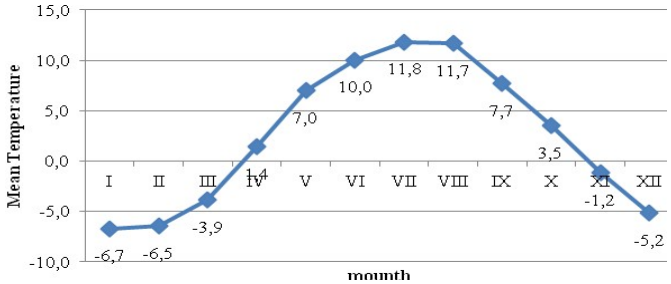

Fig. 2. The evolution of the monthly average of air temperature at Rarău (1958-2015)

In winter, multiannual averages were -6,3° C, in spring 1.5° C (with the biggest difference between April and May, 5.6° C), in summer 11.2°C and in autumn 3.3°C. The average of August month was very similar to that of July, which is typical for this latitude, August being sometimes warmer than July. From September to December the decreasing is steady month by month.

Table 1 The monthly and annual average temperature (a), maxim (M) and minim (m) values, difference between them (d), at meteorological station Rarău (1958-2015)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	An
a	-6.7	-6.3	-3.9	1.4	7.0	10.0	11.8	11.7	7.7	3.5	-1.0	-5.2	2.5
M	-2.7	-0.2	0.4	5.1	12.5	13.3	16.1	15.5	12.6	7.9	3.1	0.4	
	1999	2014	1990	1989	2008	1964	2012	1992	1994	1966	2010	1960	
m	-13.6	-12.6	-9.3	-3.6	3.4	7.5	9.0	7.7	3.1	-0.7	-7.3	-9.9	
	1963	1985	1987	1997	1991	1984	1979	1976	1996	2003	1986	2001	
d	10.9	12.4	9.7	8.7	9.1	5.8	7.1	7.8	9.5	8.6	10.4	10.3	

If in August the average is very close to the maximum of July, beginning with September, the average drops by 3 degrees, reaching in December to -5.2° C. Similar to the situation between July and August, the average temperature in February is close to that of January.

The monthly average temperatures are negative 5 months a year, which shows, in addition to the influence of altitude and the northern part of Romania and the high frequency in cold season of the advection of cold arctic or polar air, from N, NE and E and a weak cyclonic activity (tab. 1). In winter, thermal inversions frequently

occur and there are also hours whe the Rarău Masiff is warmer than on the Bistriţa or Moldova valleys. The highest January average was-2.7°C, and the lowest -13.6°C (tab. 1, fig. 3). The highest July average was 16.1°C and the lowest 9.0°C. The greatest variability between extremes averages was recorded in February, the month in which the dynamics of the atmosphere has a greater variability.

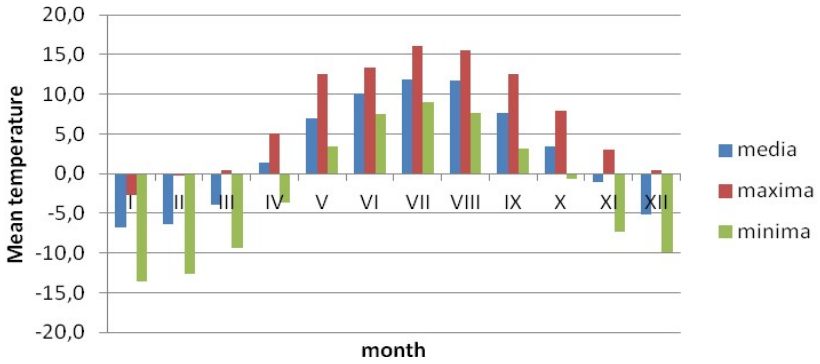

Fig. 3. The monthly and annual average temperature, highest (maximum) and lowest (minimum) the monthly average difference between them, at meteorological station Rarău, from 1958 to 2015

The low monthly averages generates depths of frost in the ground in a greater extent than the values of the daily minimum extreme temperature. This thing is more important for the lower area from the base of Rarău Massif, especially for crops and natural vegetation is usually better suited to the local conditions.

Tab.2. The monthly and annual maximum (M), minimum absolute (m) and the their amplitude at the meteorological station Rarău (1958-2015)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
m	-25.2	-27.4	**-27.7**	-15.0	-8.0	-3.3	0.1	-0.7	-7.4	-14.4	-20.3	-25.1
M	10.0	11.4	18.1	20.2	23.8	27.0	**29.0**	27.4	24.8	19.8	16.2	10.1
A	35.2	38.8	45.8	35.2	31.8	30.3	28.9	28.1	32.2	34.2	36.5	35.2

The monthly and annual (maximum and minimum) absolute extremes (tab.2) reveals the opportunity of high mountain area, to record annual absolute minimum in early March. Absolute monthly maximum amplitude is recorded during this month, late in winter and early in spring, in this area there are periods with intensive atmospheric circulation. The absolute minimum occurred on 4th march 1987, in the condition of a north northeast polar air advections and the absolute

maximum occurred on the 13th July 1984, when it produced a northwest subtropical air invasion from Africa (fig. 4).

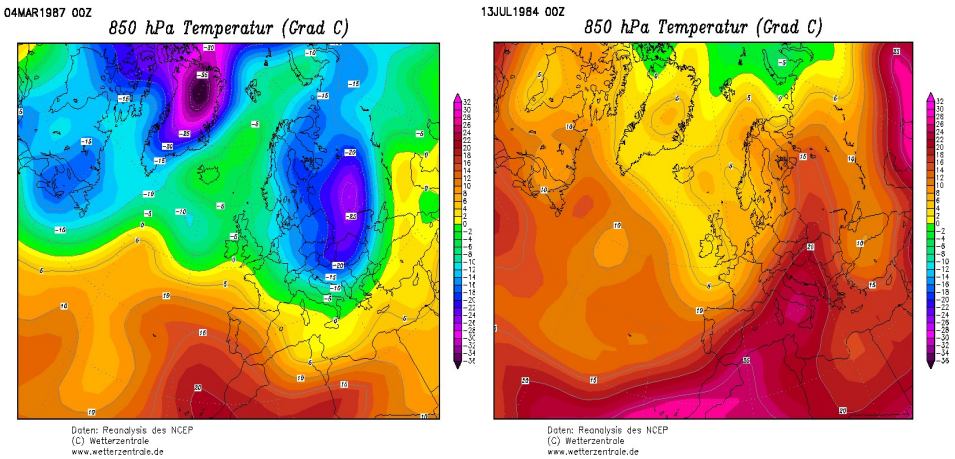

Fig. 4. The temperature (°C) at 850 hPa in Europe in the date of absolute minimum (a) and the absolute maximum (b) at meteorological station Rarău (www.wettercentrale.de)

The absolute extremes are values that appear isolated, the daily maxima and minima average, characterize better the appearance within of maximum and minimum temperatures (Dumitrescu, 1972), (tab. 2 and fig.5).

Tab. 2. The monthly and annual averages of daily maximum (M) and minimum (m) temperatures and the difference between them (D), at the Rarău meteorological station (1956-2006)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
M	**-3.7**	-3.2	0.0	5.2	10.9	14.2	**16.1**	16.0	11.9	7.4	1.8	-2.4	**6.2**
m	**-9.7**	-9.6	-6.8	-1.5	3.6	6.6	**8.3**	8.2	4.5	0.6	-4.3	-7.9	**-0.7**
D	5.9	6.4	6.9	6.6	7.3	7.6	**7.8**	**7.8**	7.4	6.8	6.1	**5.5**	**6.9**

The average number of days with different characteristic temperatures could be noticed at Rarău meteorological station and their regime is shown in tab. 3 and fig. 5. A high number of days with frost could be noticed, occupying on average half from the number of days of the year, almost all the winter and over 85% of the cold semester days, missing only in July.

There are 3.5 months of winter days, missing only in July and August and frosty days approximately 1.5 months per year, missing only from May to September.

The average number of summer days is insignificant, 4.7 days, which may occur only during summer months (*Tab. 3 and Fig. 6*).

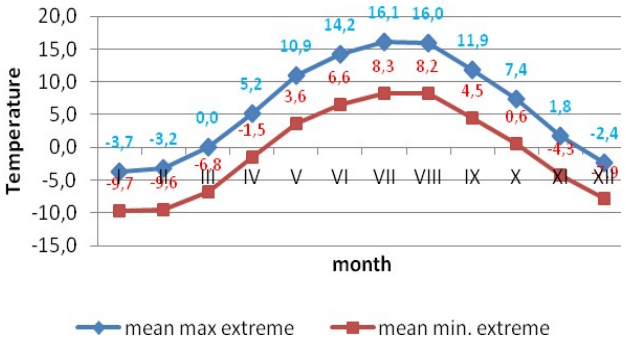

Fig. 5. The monthly averages regime of daily maximum and minimum temperatures at the Rarău meteorological station from 1956 to 2006

Tab. 3. The average number of days with different thermal characteristics at the Rarău meteorological station (1956 to 2006), (Frosty nights, Tmax ≤ -10^0,**Fn**; Winter days, Tmax ≤ 0^o **Wd**; Days with frost,Tmin ≤ 0^o , **Df**; Summer days, Tmax ≥ 25^0 ,**Sd)**

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	year
Fn	13.7	12.9	9.2	2.4						2.1	5.6	9.8	**55.6**
Wd	23.5	20.0	15.3	5.22	1.1	2			1.5	4.58	11.8	21.5	**106.5**
Df	30.5	27.7	28.2	19.0	6.3	1.9		1	4.9	13.7	22.4	29.0	**184.6**
Sd						1.3	1.2	2.2					**4.7**

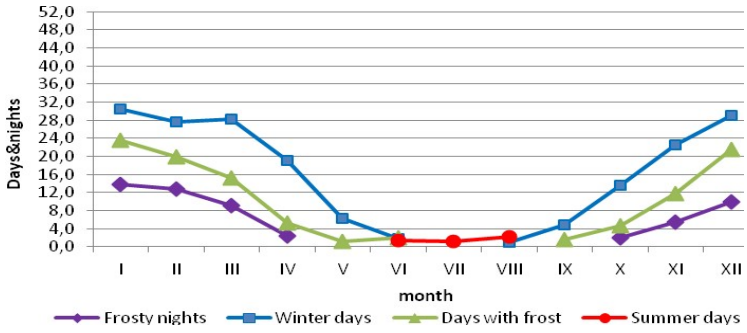

Fig. 6. The annual regime of average number of days with different thermal characteristics at the Rarău meteorological station (1956-2006)

The annual average temperature variation

For the period 1958-2015 were calculated values deviations (from year to year), of the average annual temperatures compared to yearly averages 2.5°C. The higher values than the annual average were recorded in 36.2%, reaching a maximum of 1.9ºC in 2014 (Figure 7).

The frequency of 63.8% of the number of years of negative deviations from the multiannual average shows that the colder years are more than warm ones, and this is "normal" thing, but with small averages below the annual average (-1,2°C), with a maximum negative deviation of -1.3°C in 1980. Only in two years, 1967 and 2000, the annual average air temperature value was equal to the multiannual average (fig.7).

Although there is greater consistency among multiannual average compared to lower areas, opening towards the eastward and relatively towards westward favorise a greater variability than predicted for this altitude.

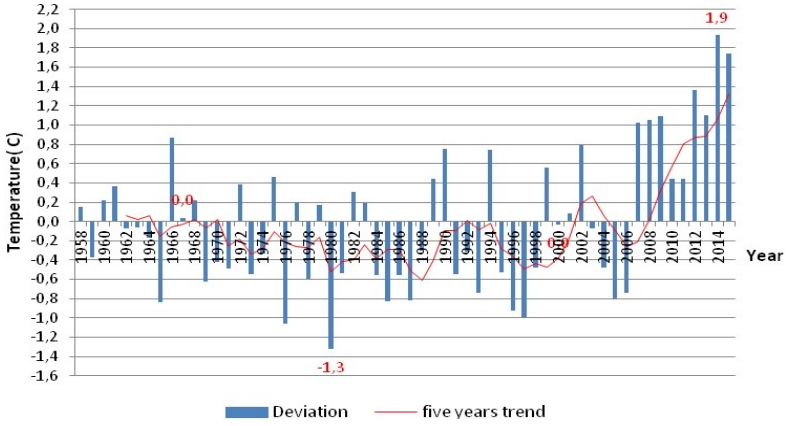

Fig. 7. The variation of annual average deviation compared to the multiannual average at Rarău meteorological station (1958-2015)

The thermal characteristic of the years according to Hellman criteria is presented in tab. 4. As we notice in the earlier analysis, notes that prevails cold years (1965, 1969, 1978, 1984, 1985, 1986, 1987, 1993, 1996, 1997, 2005 and 2005), while 1976 and 1980 were colder years. 1966, 1990, 1994, 1999, 2002 and 2007 are considered the warmest years. The last 4 consecutive years (2012, 2013, 2014 and 2015), which reveals the fact that there is a worrying trend of the high mountainous area.

Conclusion

In 51.72% of the analyzed years, the annual average was lower that annual average (2.5oC); the annual average was superior to the multiannual average in 44.83% and only in 3.45% of the causes the averages were equal.Regarding the monthly average, this represents the normal course, an increase in spring and a

decrease in early autumn and the biggest differences there are among the months of transitional seasons. In those 58 years, positive deviations from the annual average were 36.2% from these years and negative deviations 63.8% from these years. Between 1962 and 2006 there have been cycles of 3-4 years with negative deviations, interrupted by positive deviations by 1 or 2 years. Thus, between 1962-1965, 1969-1971, 1984-1988, 1991-1993, 1995-1998 and 2003-2006 there were periods with negative deviations from the annual average, between 0.1°C and 1°C. From 2007 to 2015, the deviations were positive, with values between 0.4°C-1.9°C (2014). There is a cold period of 4 consecutive years (1984 -1987) and a period of warm years (2012-2015). In the high mountainous area the inertia of ocean space was submitted, global warming being felt later than the land area.

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