Carpathian Journal of Earth and Environmental Sciences, February 2011, Vol. 6, No. 1, p. 43 - 50

GLOBAL CLIMATE CHANGE–RELATED PARTICULARITIES IN THE RODNEI MOUNTAINS NATIONAL PARK

Carmen–Sofia DRAGOTĂ[1] & Gheorghe KUCSICSA[1]

[1]*Institute of Geography, Romanian Academy, Dimitrie Racoviță, 12, Bucharest, dragotacarmen@yahoo.co.uk, mondy_ghe@yahoo.com*

Abstract: A series of aspects in the evolution and characteristic features of some environmental variables are clearly related to global climate change, some climatic variables being major indicators of this change-induced disturbances. In the Rodnei Mountains National Park, at the Weather Station Iezer, some manifestations of global warming are visible in the evolution of air temperature and of the quantity of precipitation, particularly in the warm season of the year. As significant is the effect of the variation in the major climate indicators connected directly with the thermal and/or precipitation regime. Some of the main indicators analyzed in this paper suggest that multi-annual mean temperatures and shower days are increasing, while the annual precipitation mean and snow pack thickness are decreasing, foggy days and liquid precipitation become more numerous, solid precipitation days being ever fewer. All these aspects are relevant of the extent to which the study-area is being affected by global climate change.

Key-words: climate change, Mountains Rodnei National Park.

1. INTRODUCTION

Climate change is the main challenge for the international community these days, being the most complex globalised environmental issue with impact on the economy, society, human health, the state and quality of life, as well as of biodiversity. The United Nations Framework Convention on Climate Change (1992) defines climate change as change of climate which is attributable directly or indirectly to human activity that alters the composition of the global atmosphere and which, in addition to natural climate variability, is observable over comparable time periods.

In the mountain region, climate change has a direct impact on the zonal layout of vegetation, and sooner or later the soil will suffer as well, with direct repercussions on natural habitats and land-use. Some researchers (Barry, 1992; Beniston, 2000; Richard & Terence, 2003) affirmed that the mountainous environment would respond more vigorously to future climate change. Some plant species, unable to adapt themselves to higher temperatures, would become extinct. The forest ecosystems would undergo some alteration, particularly in the distribution of vegetation belts. At the same time, also the plant growth season might extend (IPCC Technical Paper, 2002). High risk areas are those in which some species have come close to their biological limits. As a result, the boundaries of vegetation belts will tend to rise, presenting visible modifications especially in the timberline area. On the other hand, as the line of perennial snows rises, glaciers tend to shrink, while the migration of certain vegetal associations will reduce sub-alpine and alpine areas (Bălteanu et al., 1987). Climate change can alter the frequency of extreme or rare events that pose hazards to life and property in mountain regions. As such events often cause great loss of life and severe impact on the local economies, an understanding of the modification produced in exposure to hazard is critical to sustainable adaptation to global change (GLOCHAMORE Research Strategy, 2006).

2. STUDY-AREA

The Rodnei Mountains National Park is part and parcel of the Rodna Mountains situated in the North of Romania, approximately in the central part of the Carpathian Chain (Fig. 1). The Park itself lies at some 1,600 m a.s.l., basically between 700 m and 2,300 m (Pietrosu Peak), featuring one of the most imposing alpine landscapes in the Romanian Carpathians that preserves the most representative glacial and periglacial landforms. Its climate, high altitude, massiveness and relief aspect, make of the Rodnei Mountains National Park a landmark for Romania's Eastern Carpathian space.

According to a Climatic Regionalization Plate (Bogdan, 2002), the Rodnei Mountains Natural Park covers an area of both lower and higher mountains and has a moderate continental climate with gentle North-Atlantic influences. Because the Park lies at high altitudes in the North of the Eastern Carpathians, the Rodna Mountains are crossed by air masses (Atlantic) from the West and subsidiarily by polar ones from the North and North-East.

The multi-annual air temperature means vary with altitude and relief configuration between –2°…0°C on the tallest peaks and from 6°…8°C in the extreme South of the Park. On the highest summits temperatures stand between 0° and 2°C up to 4°C in the median slope sectors and 6°C in the valley corridors (especially in the South of the Peak) (Fig. 2).

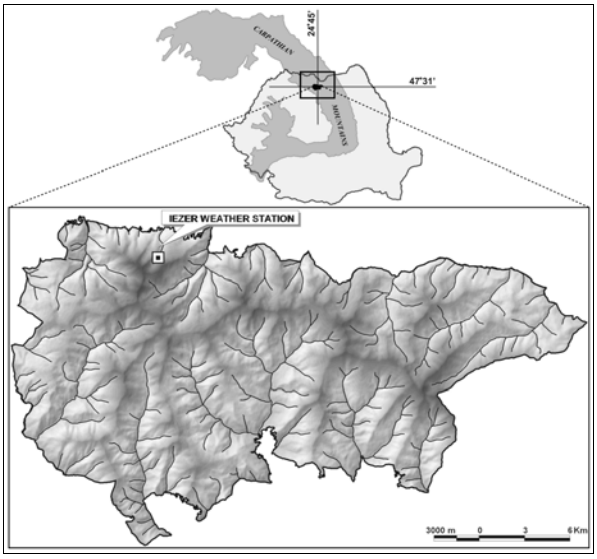

Figure 1. Location of the study-area in Romania and in the Carpathian Chain.

Looking at the annual mean temperature series, it appears that there are periods in which significant deviations from the multi-annual mean occur (Fig. 3), basically there are years in which the mean values stood close to, or above 2.5°C (1982, 1994, 1999, 2000, 2002, 2007), while in other years mean values fell to 0.5°C (1976, 1985), or to 0.2°C (1980). Monthly average temperatures over the year developed normally, with a low in January and a high peak in July. Monthly means ranged from –6.9° to 10.1°C. The absolute minimum of –29.0°C was registered on August 3, 1998.

As in the case of temperature, the quantity of precipitation is unevenly spread within the Park. At heights above 2,000 m, due to atmospheric fronts and advections, annual quantities are estimated of over 1,400 mm (multi-annual mean). On the 2,000 m-high summits the multi-annual mean is estimated between 1,200 – 1,400 mm, around 1,000 m or even below (800 – 1,000 mm) in the valley sides from the South of the Park (Fig. 4). The multi-annual precipitation mean of ca. 1,250 mm (Iezer Weather Station), registered significant variations from one year to the next throughout the observation period. In general, both positive and negative deviations average 150 mm (Fig. 3).

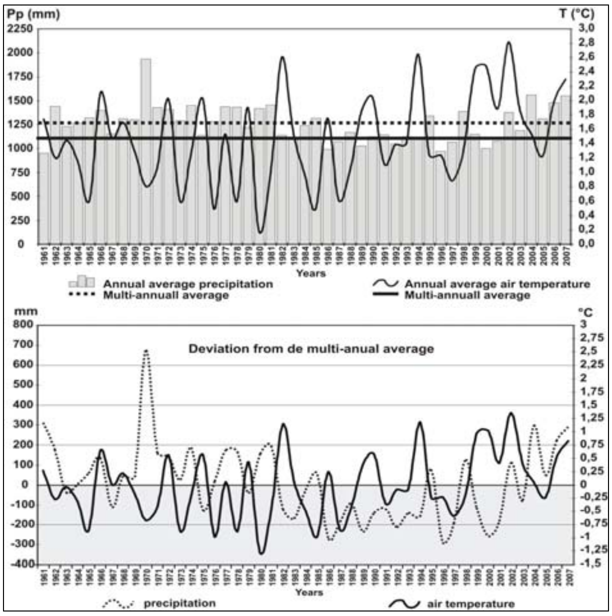

Figure 3. The annual mean quantities of precipitation and mean temperature and deviations from the multi-annual mean (Iezer Weather Station).

Positive deviations appear to prevail in the first part of our observations (1961 – 1981), and especially after 2003, when average quantities were in excess of 200 mm. In the latter half of the observation period (1982 – 2003), mainly after 1989, average quantities came close to 180 mm, with an absolute annual maximum of 1,935.1 mm in 1970. That year, the monthly means were in excess of 125 mm, top quantities being reached in February and May (ca. 250 mm monthly mean). The absolute annual minimum of 951.3 mm was registered in 1961, when monthly means were under 50 mm (January, February, October and December) and even under 10 mm (September).

As a result, at over 1,700 m solid precipitation begin falling in the latter half of September, at lower altitudes in October, the last snowfalls being recorded in May; on the highest summits snow may fall also in summer, the Iezer Station recording it over the past few years in July and August, the hottest months of the year.

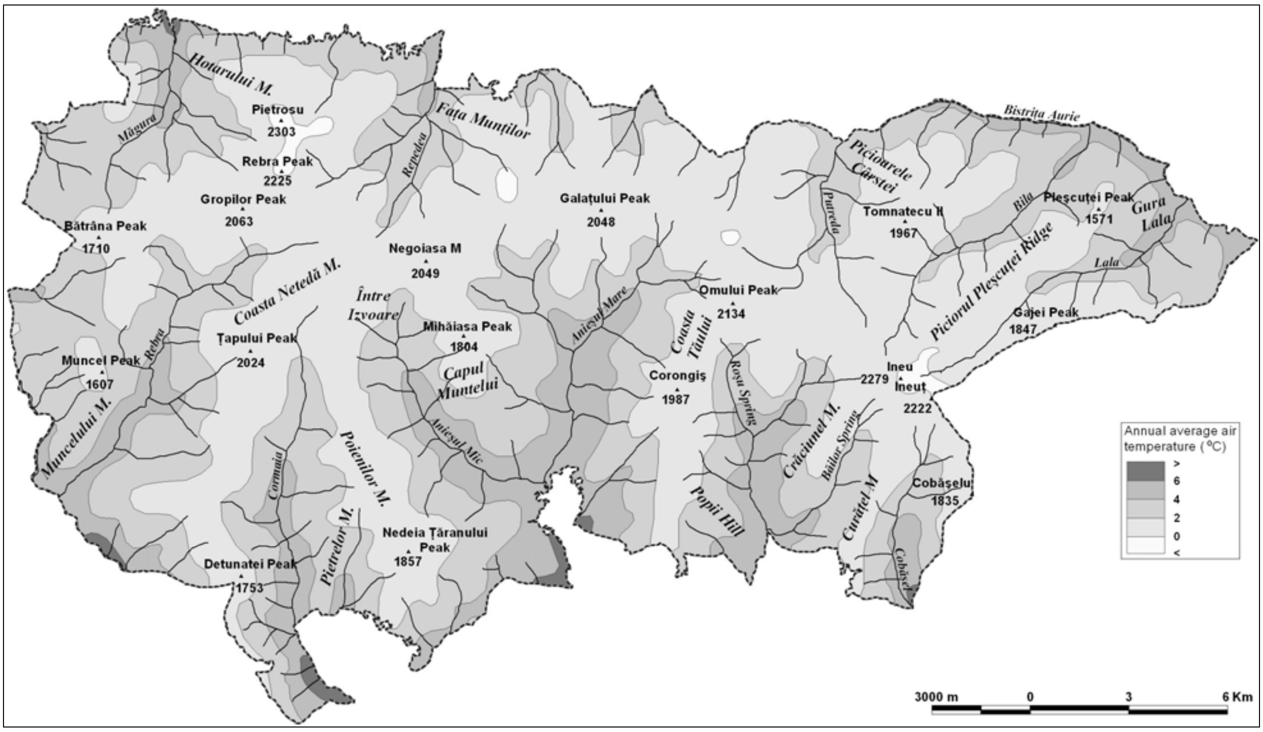

Figure 2. The distribution of annual air temperature means (1961 – 2007) in the Rodnei Mountains Natural Park.

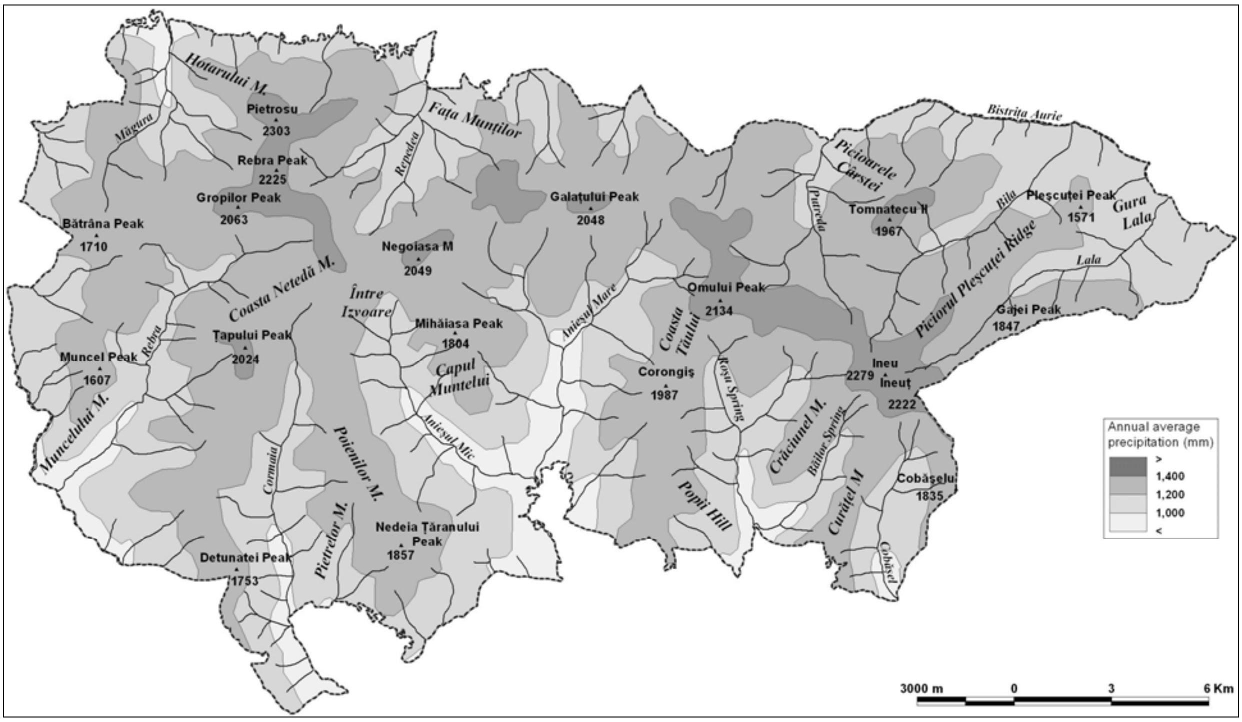

Figure 4. The distribution of the annual mean quantities of precipitations (1961 – 2007) in the Rodnei Mountains Natural Park.

The multi-annual mean of snow-pack thickness is 55 cm (Iezer Weather Station), pack values (ca. 120 cm) having been registered in 1961 and 1995. On the highest summits and in sheltered places the snow layer might be over 150–200 cm thick. Although perennial snow is missing, yet snow can be seen in sheltered places facing north as late as the end of summer, and occasionally lasting from one year to the next.

3. METHODOLOGY

The present analysis relies on the observation data recorded over 1961 – 2007 at Iezer Weather Station (Table 1) situated at 1,770 m altitude, on the Northern side of the Rodna Mountains (Fig. 1), at the lower tip of the Iezer glacial cirque, some 5 km away from Borşa Town.

Table 1. Multiannual mean of the climatic parameters recorded at Iezer Weather Station (1961 – 2007).

Air temperature (°C)	**1.5**
Quantities of precipitations (mm)	**1261.5**
Number of the days with rain	**100.1**
Number of the days with snow	**113.4**
Number of the days with rain shower	**76.0**
Number of the days with snow shower associated with snow grains	**44.6**
Snow pack thickness (cm)	**16.2**
Relative humidity (%)	**27.9**
Number of the days with fog	**157.9**

Maps of the annual and multi-annual temperature an the precipitation means have been drawn up by correlating weather observation data registered mainly at Iezer Station with a set of similar observations made at adjacent stations, e.g. Ocna Şugatag, Sighetu Marmaţiei, Bistriţa, and Câmpulung Moldovenesc as well as at representative gauge points (Cârlibaba, Borşa, Vişeu de Sus, Romuli and Sângeorz-Băi). Based on correlation graphs of altitude, massiveness, aspect and value of the climatic variables used the isolines of annual and multi-annual means of air temperature and quantities of atmospheric precipitation have been traced. Generalizing and vectoring the above has been achieved with the help of Geographical Information Systems.

Climate data are graphically represented by several diagrams depicting, by means of a mathematical relation, the trend of global climate change relevant for profile studies. The trend itself represents the slow, lengthy variation of the studied variable, suggestive of the general direction of its evolution in time (Patriche, 2003). It is known that the linear model assumes that the rate of increase or decrease is constant and the linear model is very sensitive to outliers (Hobai, 2009).

The trend result obtained was verified by the Mann-Kendall test, which is currently the widely-accepted approach to global climate change. As suggestive proved to be the value-class representations, emphasizing the variability of the analysed climatic variables over certain periods of time.

4. RESULTS

4.1. The variability of temperature and of precipitation quantities

The value-class method used in the graphical representation of climate variables reveals the changes occurred in the air temperature mean and in the quantity of precipitation after 1984 and 1987, respectively, when discontinuities appeared in the direction of their evolution (Fig. 5). The results were verified also by the Mann-Kendall test (Micu & Micu, 2008).

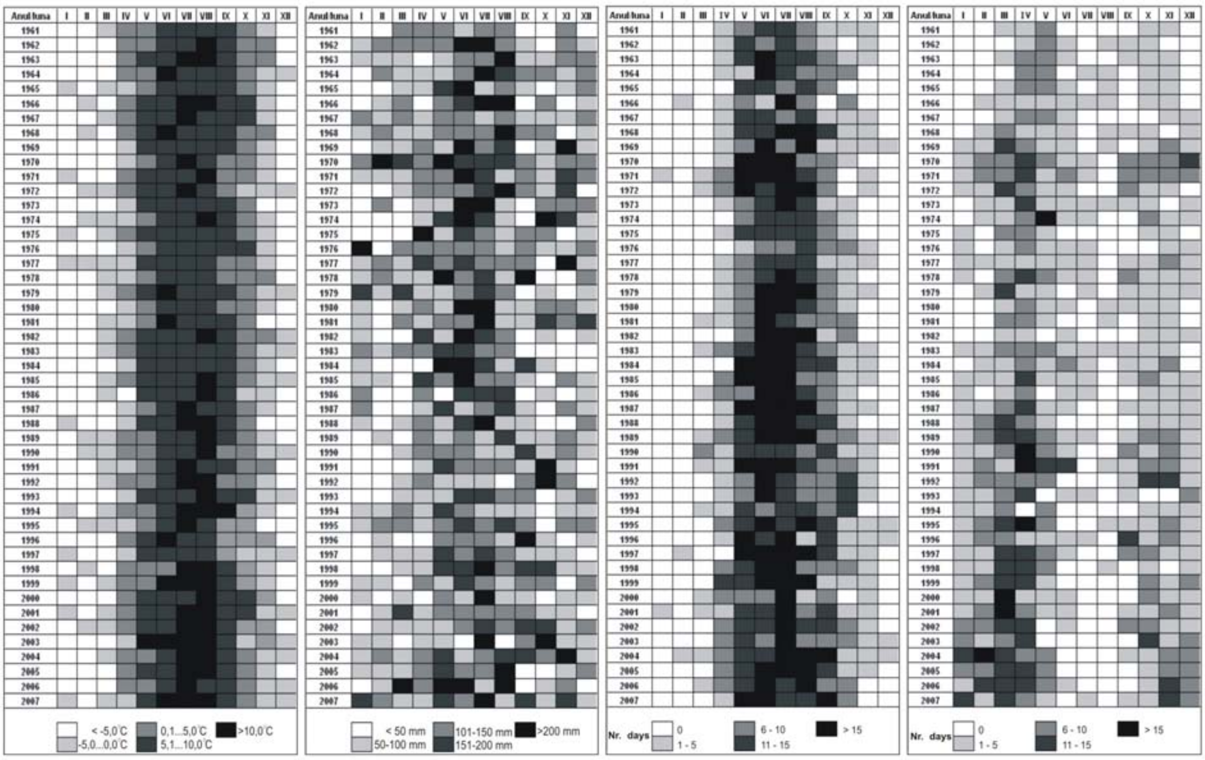

Figure 5. A value-class representation of variability in temperatures, precipitation quantities and number of the days with rain shower and number of the days with snow shower associated with snow grains (Iezer Weather Station).

The Iezer Weather Station records show the annual temperature and precipitation mean to fluctuate around a multi-annual value of 1.5°C, with an increasing tendency over 1961 – 2007 at a rate of 0.7°C and of 0.9°C in the warm season, that is, by 0.2°C more than the general annual trend (Fig. 6). The cold season rate of 0.6°C is by 0.1°C lower than the annual one.

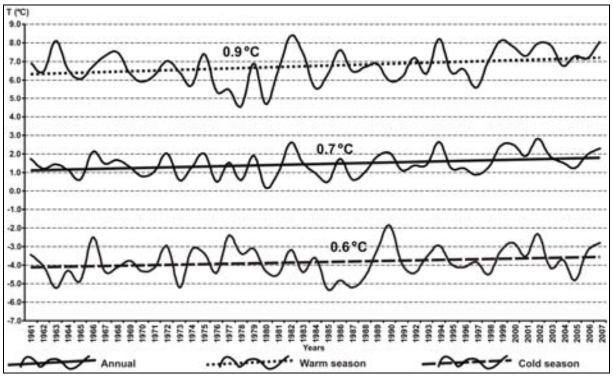

Figure 6. A comparative graph of annual and seasonal mean air temperature (Iezer Weather Station). Evolution trends.

The average quantities of precipitation/year also reveal non-periodical multi-annual variations around 1,260 mm, on average. The 1961 – 2007 period had a negative record (annual rate –100 mm), basically – 55 mm in the warm season and –35 mm in the cold one (Fig. 7).

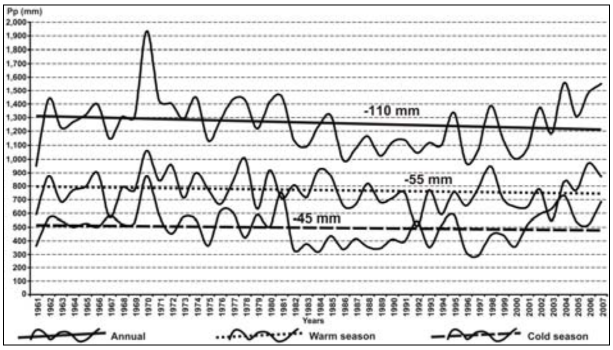

Figure 7. A comparative graph of annual and seasonal mean precipitation quantities (Iezer Weather Station). Evolution trends.

4.2. Rain and snow showers associated with snow grains

The assessment of climate change against a global warming background should take into account rain and snow showers associated with snow grains. The 1961 – 2007 period featured an average of 76 rain shower days/year, their annual frequency showing a sustained increasing trend (rate/period = 31 cases) (Fig. 8). Two distinctive periods emerged: 1) 1961 – 1983, with a maximum of 90 days in 1971, and 2) 1984 – 2007 with over 100 days (in 1989 and 2004) (Fig. 5).

Although the Rodnei Mountains National Park extends at high altitudes, and therefore rain showers are characteristic mainly of the May – August interval, yet after 1983 this phenomenon occurred more frequently over the year, e.g. in October and November and occasionally in December and March. After 1977, the number of rain shower days increased particular in June – July: >15 cases in 1980, 1984 – 1986, 1989, 1995, 1997, etc. (Fig. 5).

A similar situation in the case of snow showers associated with snow grains, annual frequency variations indicating a significant increasing trend (rate/period = 42 cases) (Fig. 5). Two distinct periods can by singed out in the observation series: 1) 1961 – 1988 with an average of 34 cases/year, and a maximum of 81 cases in 1970, and 2) 1989 – 2007 with an average of 60 cases/year and a maximum of 85 cases in 2004.

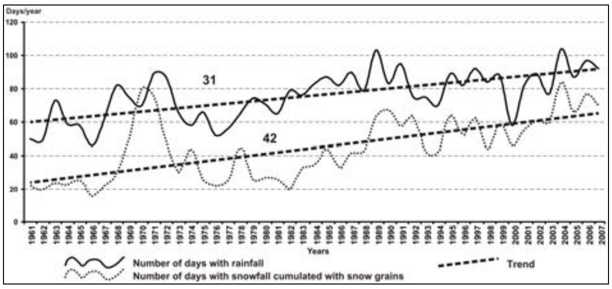

Figure 8. Variations in the number of rain and snow shower days associated with snow grains (Iezer Weather Station). Evolution trends.

The annual value-class frequency distribution of snow showers associated with falls of snow grains can be divided into two significant periods: 1) 1961 – 1985 with a September – December and February – May record of 6 – 15 cases/month on average, and a maximum of 16 cases in May 1974 and 2) 1986 – 2007, a period better represented in terms of annual frequency, that lasted from September through to May and had a value–class record of over 15 cases in April (1990, 1991, and 1995), March 2000 and February 2004. The best represented months are March and April, the absolute highest frequency of these hydrometeors being registered mainly after 1985.

4.3. Snow-pack thickness

Against the background of global climate change, the Rodnei Mountains National Park snow pack tends to decrease (Fig. 9). At the same time, the over 30 cm-thick snow layer which used to be seen in December – January would shift to March – April. Noteworthy, even though the snow pack remains only < 1 cm thick, it continues to last also in summer (Fig. 10).

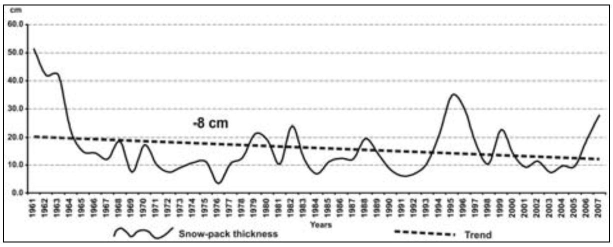

Figure 9. Variations in the snow-pack thickness (Iezer Weather Station). The evolution trend.

4.4. Fog and relative air humidity

Both these elements form a couple of current climate change indicators, particularly for the mountainous regions, and are significant whether taken apart or together. The association of these two elements with evolutions in the air temperature and the quantity of precipitation is characteristic of the climate change revealed by the profile indicators specific to Iezer Weather Station.

Thus, in regard of relative humidity, annual means tend to coincide in terms of statistics and dimension with the frequency of days with fog. The annual variation of the relative humidity mean (Fig. 11) shows a 13% decrease trend which, alongside other genetic factors, conditions a similar evolution in the frequency of foggy days (55/period) (Fig. 12).

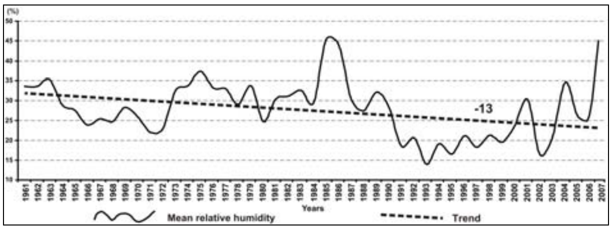

Figure 11. Variation of mean relative humidity (Iezer Weather Station). The evolution trend.

The comparative value-class representation of the monthly mean of relative humidity and fog over 1961 – 2007 clearly shows a discontinuity (1986 – 1988) in the evolution of the two variables (Fig. 10).

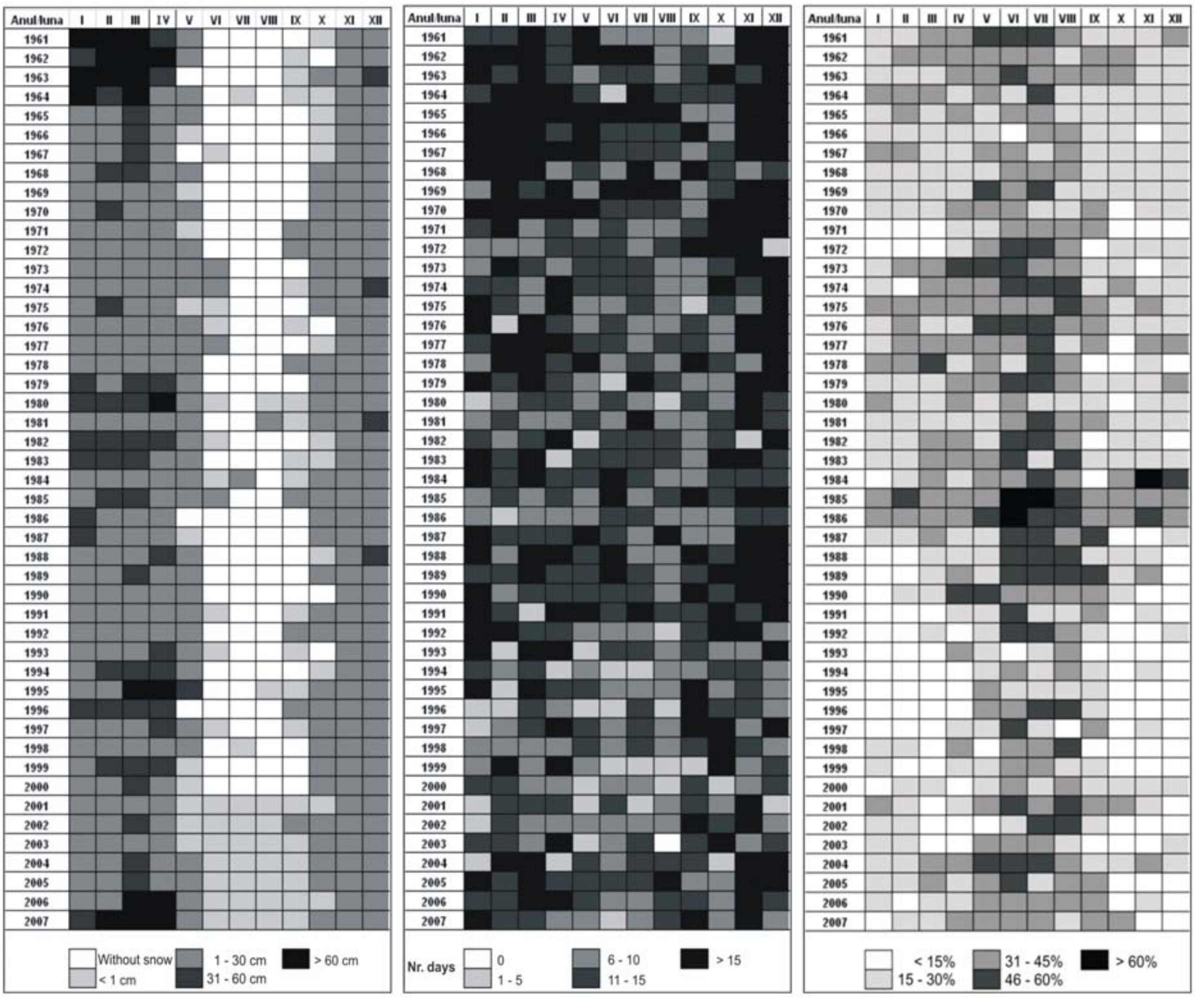

Figure 10. A value-class representation of variability in the snow pack thickness, number of the days with fog and relative humidity number of days (Iezer Weather Station).

Thus, the relative humidity value-classes reveal an increase of < 30% and particularly of <15% mainly in the cold period of the year, concomitantly with a decrease in the incidence of foggy days (<15 cases/month), largely in the cold season, too.

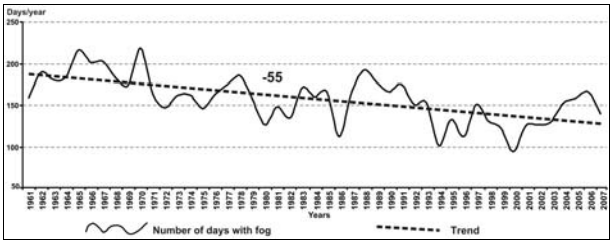

Figure 12. Variation of foggy-day frequency (Iezer Weather Station). The evolution trend.

4.5. The rain (DLpp) and snow (DSpp) ratio index

Within a global climate change context, suggestive is also the rain and snow ratio index (DLpp/DSpp ratio).

Its multi-annual calculation (Iezer Weather Station) has revealed a positive evolution trend (Fig. 13) given that rainfalls were more frequent than snowfalls.

At the altitude of Iezer Station and in the conditions of the dominant annual atmospheric circulation there, liquid and mixt precipitation seem to prevail especially at the end of autumn and the beginning of winter. This trend is largely explainable by the multi-annual increase of air temperature values.

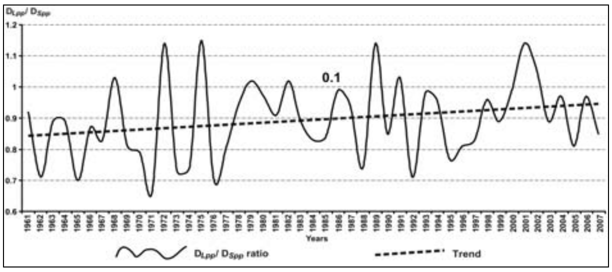

Figure 13. Variation in the DLpp/DSpp ratio (Iezer Weather Station). The evolution trends.

4.6. "De Martonne" dryness index

"De Martonne" dryness index, which is important for assessing global climate change (de Martonne, 1926), represents the ratio between the annual mean of precipitation quantities and of temperature, indicating climate variability over a year, period, month, or season: IdM = P/(T+10), where P (mm) = annual mean quantity of precipitation, and T(°C) = annual mean temperature. Having in view that, by definition, the index values increase with altitude, it follows that they are the more elevated the higher the altitude where temperatures are lower and precipitation more abundant. And reversely, at lower altitudes, where temperatures are higher and precipitations are depleted, index values are reduced. The graph of "de Martonne" index value variation (Fig. 14) indicates that these values tend to decrease (the dryness process being inversely proportional to calculated index values). The 47-year Iezer Station records studied, suggest obvious temperature increases and lower quantities of precipitation, particularly after 1992.

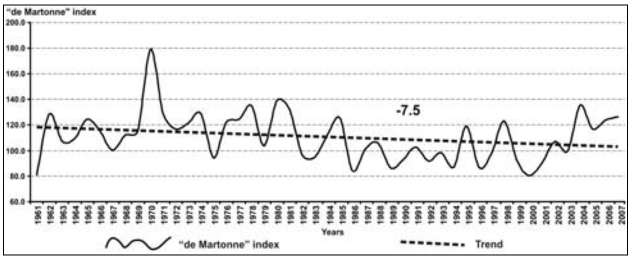

Figure 14. Variation in the "de Martonne" dryness index (Iezer Weather Station). The evolution trend.

5. CONLUSIONS

Global warming signals in the Mountains Rodnei Natural Park have been highlighted by the evolution of the thermal and pluviometric variables, as well as by the results obtained in processing the most significant climatic indices and indicators registered at Iezer Weather Station over the 1961 – 2007 periods. Thus, the multi-annual air temperature mean was increasing at a rate of 0.7°C/period, while annual precipitation quantities tended to decrease at a rate of –100 mm/period.

The indices and indicators directly connected with the thermal and/or pluviometric regime reflect changes of frequency and intensity under the impact of global change, particularly a sustained trend in the higher frequency of rain showers (at a rate of 31 cases/period), of snow showers associated with snow grains (at a rate of 42 cases/period), and of rainy days compared to snow days. The association of relative air humidity with the frequency of foggy days indicates a decreasing trend, statistically-expressed by an average rate of –13%/period and –55days/period, respectively. And last but not least, a significant climate change aspect in Rodnei Mountains National Park after 2000 is the persistence of the snow layer in summer, too, even though it is but 1 cm thick.

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Received at: 22. 03. 2010
Revised at: 16. 09. 2010
Accepted for publication at: 23. 09. 2010
Published online at: 27. 09. 2010