SNOWSTORM – A CLIMATE RISK PHENOMENON IN PARÂNG MOUNTAINS

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La tempête de neige est un phénomène climatique qui se passe durant l'hiver mais également en dehors des limites de saison, qui perturbe les activités humaines, et qui démontre ainsi des caractéristiques de hazard naturel. La tempête de neige a un impact négatif sur les activités humaines sous l'effet combiné de deux éléments: des vents de grande vitesse et d'abondantes chutes de neige. Dans les montagnes Parâng, les conséquences engendrées par les tempêtes de neige se traduisent le plus souvent par des bloquages et relentissements sur les routes touristiques, en particulier le long de la crête (où des décès ont été recensés), interrompant le trafic sur la route nationale 67C entre Novaci et la région touristique de Rânca.

L'objectif de cet article est d'identifier le caractère aléatoire et la dangerosité du phenomena (hazard) de tempête de neige et ses conséquences potentielles en termes de dommages matériels et environnementaux et/ou en termes de victimes dans les montagnes Parâng

Keywords: snowstorm, Parâng Mountains, impact, risk.

1. Introduction

In the latest years, thoroughly studying and deep understanding of hazardous phenomena (snowstorm included) have become mandatory, so as to achieve as accurate as possible forecasts, in order to reduce the large number of victims and the economic damages.

As regards the mountainous environment, natural hazards and risks are the result of the temporary intersection of certain environment conditions mainly pertaining to geological structure, morphological and morphometric disposition of the active surface, state and dynamics of the atmosphere or the flowing manner of surface waters. All these superpose an intensely human-

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modified environment by various activities (tourism, cattle breeding, forestry and mining), with which it interacts (Săndulache, 2010).

In the Romanian scientific literature (Cheval, 1999), the hazard is considered to be the most comprehensive term used to define natural sensitive phenomena. The term of hazard is close correlated with the one of risk. The hazard is a phenomenon that can have severe consequences and negative impacts on the society and natural environment, which means that it can induce the risk. The hazard is focused on the causes while the risk is focused on likely potential consequences (Bogdan, Marinică, 2007).

Of those phenomena, snowstorm is a very complex one, being defined as a snow transport above ground surface, caused by sufficiently strong and turbulent wind, accompanied or not by snowfall (Ţâştea *et al.*, 1965). In Parâng Mountains, snowstorm is a winter phenomenon present each year. Its regime is non-uniform in time and space due to the large variability of the atmospheric circulation and the local relief conditions which imprint certain nuances.

The snowstorm has been analysed across country overviews (Bălescu, Beşleagă 1958, 1962, Beşleagă, Ciucă, 1979) or case studies, which refer to this phenomenon (Gaceu, 2005, Marinică, 2006, Bogdan, 2008).

2. Study Area

Parâng Mountains are a subunit of Southern Carpathians, being situated in their central-western part , in the homonymous mountain group (*Figure 1*). Parângul Mare Peak has the maximum altitude in the mountainous massif (2519 m.a.s.l), thus being the second highest in Romania and the most representative within the Parâng Mountains Group. As regards the climate, it displays high mountains characteristics, prone to the occurrence of both summer and winter hazardous weather phenomena.

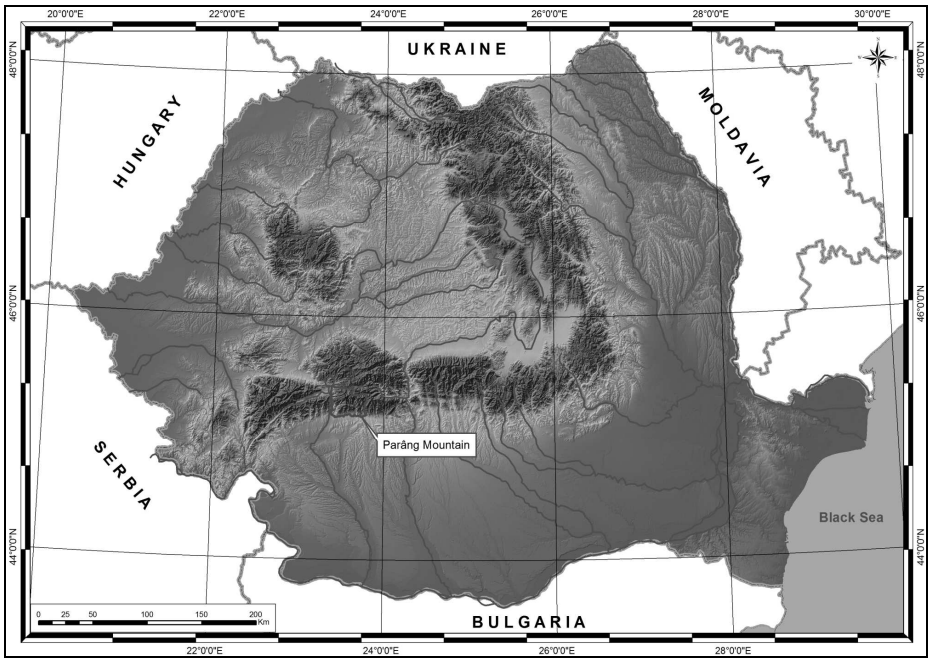

Fig. 1. Geographic location of Parâng Mountains

3. Methodology

The database is made up of (monthly and annual) mean and maximum climate data series over 20 years (1983-2002) from Parâng and Petroşani weather stations. For comparison purposes, data from Bâlea Lake and Omu Peak weather stations were also used.

In view to establish the hazardous character of this phenomenon and its potential to cause human deaths, along with material and environmental damage in the study area, the following methodologic approaches were completed (Bogdan, 1996):

- the average characteristics of the analysed atmospheric phenomenon were established, which gave us the general picture of a climate element able to generate a risk;
- maximum values were extracted representing the possible variation limits and the risk thresholds (risks are highlighted as climate extremes);
- deviations of the studied climatic parameters were computed against the multiannual mean, considered normal, which allowed settling the risk threshold;

- the snowstorm occurrence likeliness (spatial probability) having hazard character was established through correlating the identified climatic indicators;
- vulnerability was estimated and risk exposure was established through charting the most important properties as well as activities and inhabitants (Sorocovschi, 2007); those indicators were selected and quantified so as to describe the vulnerability of these elements to a climatic hazard. Further on vulnerability was rendered cartographically.

The above mentioned methodological steps were complied with results of statistical analysis of climatologic data series with information received from local public institutions (Gorj County Inspectorate for Emergency Situations and Petroşani and Tg. Jiu Mountain Rescue Public Services), along with field observations accompanied by photos. Thus, it can be said that standard statistical processing methods were used for the computation of the mean monthly and annual values, for the extraction of extreme values and the classical methodology (Dumitrescu, Glăja, 1972) was used for the graph representation. Another work technique, increasingly used in scientific research and in many other practical activities (Haidu, 1998) is the Geographic Information System approach (Irimescu, 2014).

3.1. Climatological analysis of the **snowstorm**

The climatological analysis of the snowstorm was performed through computing the monthly and annual mean and maximum number of days with snowstorm, as well as with the interval favorable to its occurrence. Snowstorm is conditioned by negative temperatures, being marked by the mean occurrence dates of frost throughout the year, as well as by strong and turbulent wind.

The mean annual interval favorable to snowstorm occurrence widens with the altitude, as circumstances for snowfall and intense wind are more and more favorable. Thus, on the upper Carpathian level, the mean annual interval is a steady 10 months period (September to June); on the middle Carpathian level it is of 5-6 months/year (November to March), whereas on the lower Carpathian level it spans 3-4 months a year (between December and February). It is thereafter obvious that the longest interval favorable to snowstorm occurrence is the one unfolding in the alpine environment.

It can be noticed (Fig. 2) that on the lower mountainous level and mostly in Petroşani Depression, the average annual number of days with snowstorm is small (0,3 days, with an annual frequency of 0,08%) due to the local sheltering conditions. However the frequency of snowstorm increases with the altitude, although remaining small (1,2 days at altitudes of 1600 m, with an annual frequency of 0,3%). Snowstorms become more frequent at altitudes higher than 2000 m (14-26 days, with an annual frequency of over 3,9%).

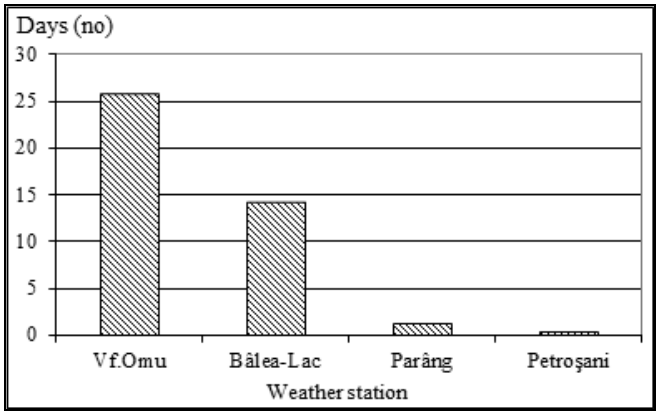

Fig. 2. Variation of average annual number
of days with snowstorm (1983-2002)

Like the mean annual interval, the *average monthly number of days with snowstorm* is influenced by altitude and local relief conditions. At the alpine level, the most numerous days with snowstorm are recorded in the winter months (2,7-5,7 days), but the phenomenon is not absent in the spring months as well, when it occurs more intensely at elevations higher than 2500 m (0,3-4,2 days) and less enhanced below 2000 m (0,1-1,6 days at Bâlea Lake weather station). In the latter mentioned area, snowstorm may also occur at the beginning of summer (0,1-0,5 days in June) but also early in autumn (0,1–0,2 days in September). On the middle and lower mountainous levels, snowstorm exclusively occurs in the winter season, with a low frequency (*Figure 3*).

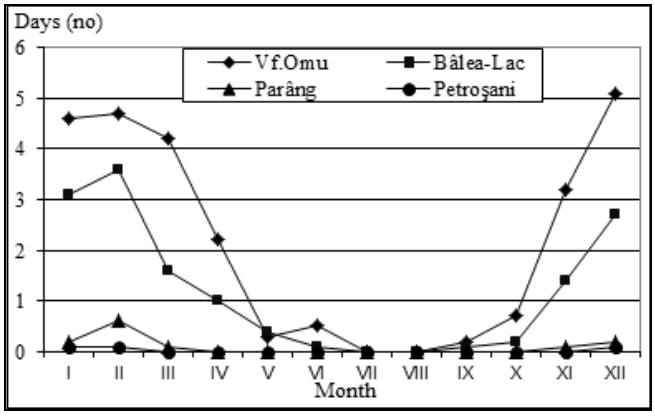

Fig. 3. Variation of mean monthly number
of days with snowstorm (1983-2002)

With regard to the frequency of this phenomenon by seasons and by mountainous level in Parâng Mountains (*Table 1* and *Figure 4*), it can be noticed that it is characteristic to the winter season throughout the massif. Its maximum frequency is encountered in the lower mountainous level (100%), decreasing with the altitude (about 80% in the middle mountainous level and 50% in the upper one). Whereas in the latter two levels snowstorm may also occur in spring and autumn, its occurrence in the alpine level is not to be excluded in summer either (with a frequency smaller than 2%).

Table 1

Seasonal frequency (%) of snowstorm occurrence

Weather station	**Spring**	**Summer**	**Autumn**	Winter
Omu Peak	26	1.9	15.9	56.2
Bâlea-Lake	21.1	0.7	11.9	66.3
Parâng	8.3	–	8.3	83.4
Petroşani	–	–	–	100

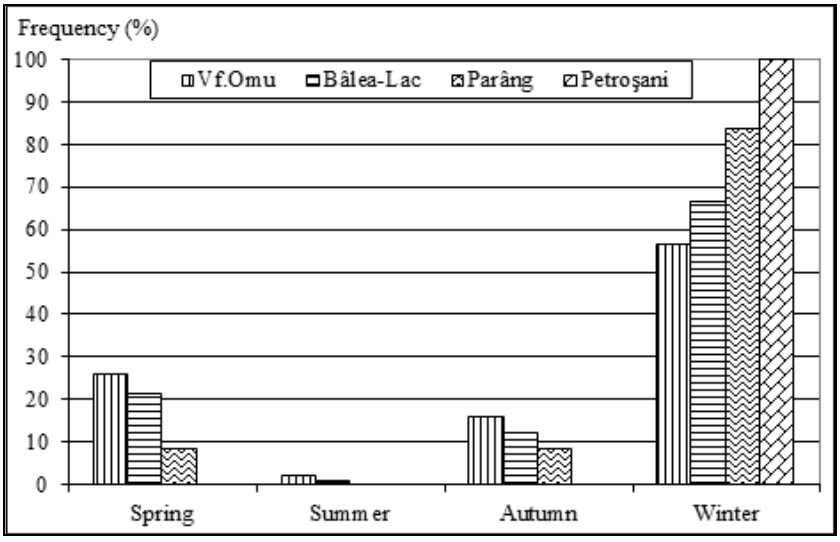

Fig. 4. The frequency variation (%) of the occurrence of snowstorms by season

Snowstorm is a phenomenon characteristic mostly to the high section of Parâng Mountains and it shows variability even if it did not occur during the whole observation interval (*Figure 5*). The absolute maximum number of days with snowstorm was recorded in Omu Peak weather station area (83 days with snowstorm in 1987), whereas the smallest number was registered at Petroşani weather station (one day in four years observation period).

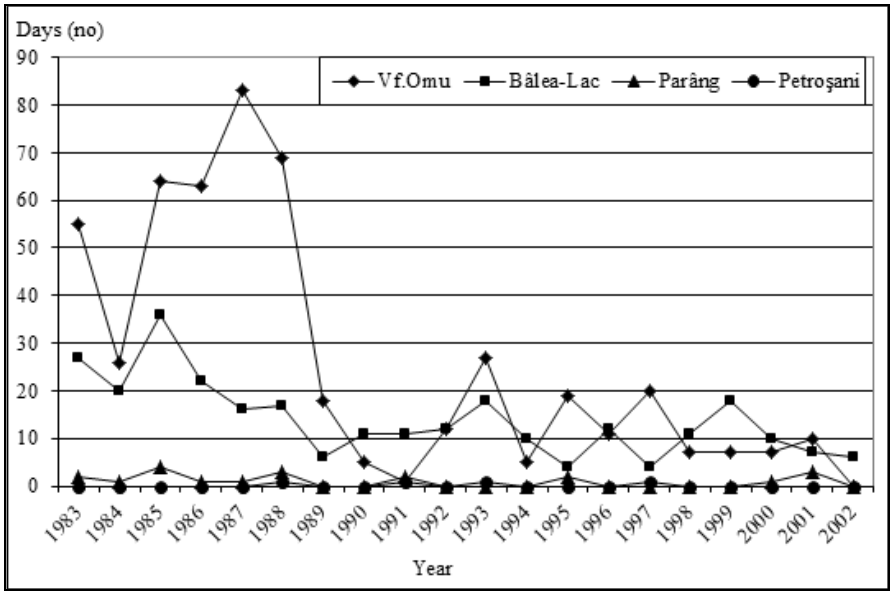

Fig. 5. Variability of annual number of days with snowstorm

3.2. Snowstorm – A Climatic Hazard.

The maximum monthly and annual number of days with snowstorm ascertains this phenomenon as a climatic hazard in Parâng Mountains. To be noted, the maximum annual number of days with snowstorm is high on the alpine level (more than 50 days) and smaller with altitude decrease (less than 10 days).

The most numerous days with snowstorm occur in the winter season at every mountain level, however with different frequency and intensity respectively: in the alpine level, snowstorms take place in December and January and is extended from 16 to 20 days; in the sub-alpine level – this phenomenon extendsfrom 7 to 15 days, in the middle alpine level – from 2 to 3 days, whereas downwards, to the foot of the massif values of less than one day with snowstorm are recorded during the winter season (*Table 2*).

Table 2

Monthly and annual maximum number of days with snowstorm

Weather station	Max. no./date	Jan	Feb	Mar	Apr	May	Jun
Omu Peak	**Max. no.**	**20**	**17**	**18**	**11**	**4**	**3**
	Date	1987	1985	1988	1987	1987	1985
Bâlea-Lake	**Max. no.**	**11**	**14**	**4**	**4**	**2**	**1**
	Date	1983	1985	1985, 1996	1984	1983	1995
Parâng	**Max. no.**	**2**	**3**	**1**	**–**	**–**	**–**
	Date	1985	2001	1987, 1988			
Petroşani	**Max. no**	**1**	**1**	**–**	**–**	**–**	**–**
	Date	1997	1988, 1993				
Weather station	**Max. no./date**	**Sept**	**Oct**	**Nov**	**Dec**	**Annual**	
Omu Peak	**Max. no.**	**2**	**3**	**16**	**16**	**83**	
	Date	1988	1986	1987	1985	1987	
Bâlea-Lake	**Max. no.**	**1**	**2**	**6**	**7**	**36**	
	Date	1996, 1992	1999	1985	1993	1985	
Parâng	**Max. no.**	**–**	**–**	**1**	**2**	**4**	
	Date			1986	1995	1985	
Petroşani	**Max. no.**	**–**	**–**	**–**	**1**	**1**	
	Date				1991	4 years **	

* data processed from Meteo Romania Archive

** whole observation period

As for the other months of the year, snowstorms may unfold mostly in the transition months (in spring and autumn) but also at the beginning of summer (in June) in the alpine level.

The aggregation of the deviations of the maximum occurring values of the snowstorm with respect to the multiannual mean of the days with snowstorm renders the probability that snowstorm acts like a climatic hazard in the environment of this mountain massif. These deviations are wide in the alpine level (where snowstorm acts more intensely in winter but also in the transition seasons and even at the beginning of summer, in June) and smaller at altitudes lower than 2000 m where it is specific only to winter season (Petroşani Depression) or to beginning of spring and end of autumn (Parâng weather station) (*Figures 6 – a, b, c, d*).

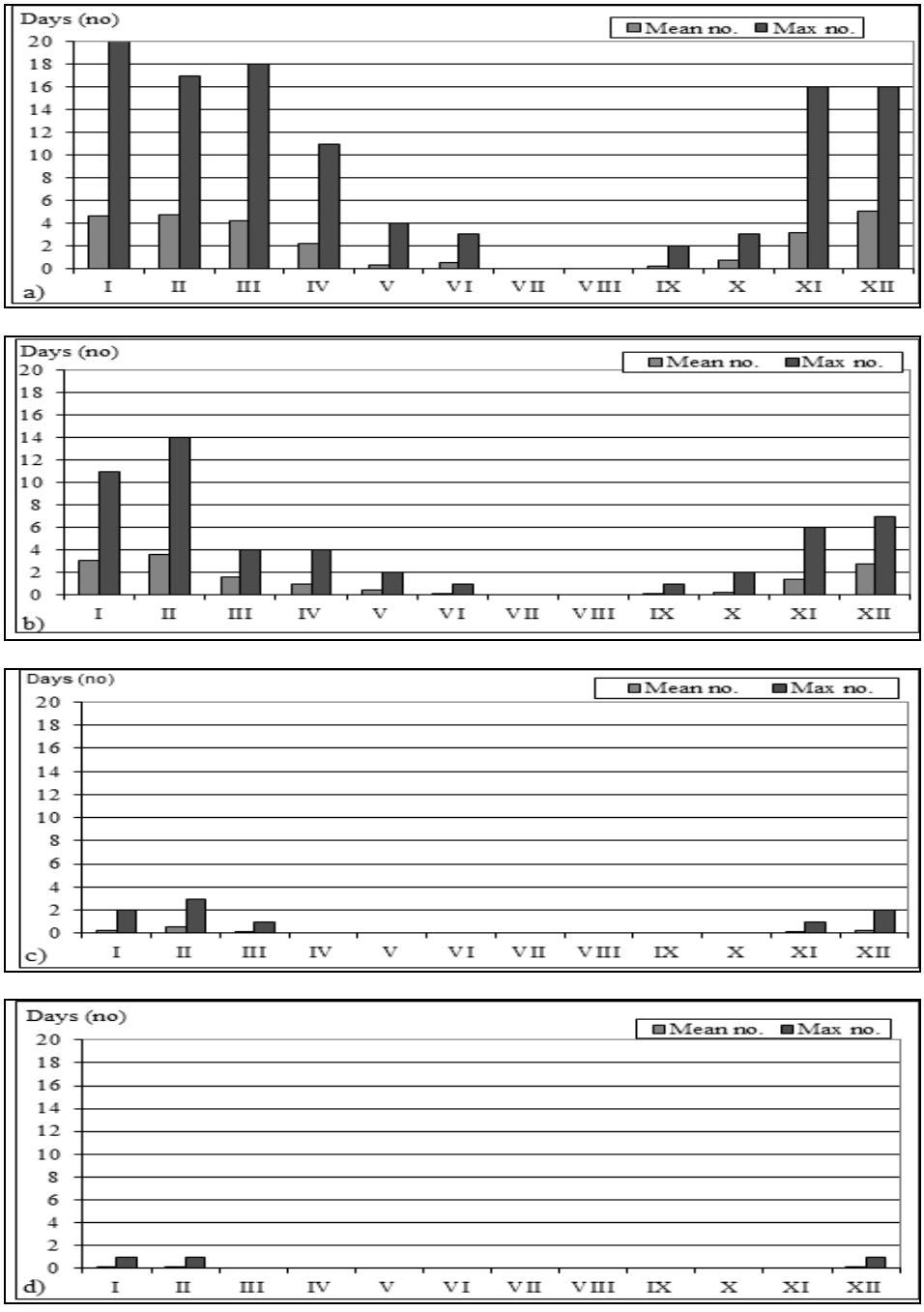

Fig. 6. Deviation of maximum number of days with snowstorm opposed to the multiannual means at: a) Omu Peak, b) Bâlea-Lake, c) Parâng and d) Petroşani

In the high area of the massif, snowstorms act like a climatic hazard not only in the cold semester of the year, when it is a hazard mostly because of its intensity, but also at the beginning of the warm season, in June or at autumn start, in September. Although it is a winter-specific phenomenon, in the upper mountainous level it is characteristic to the spring season, too.

In the middle mountain level, snowstorm unfolds with various intensities especially in the cold season but may also occur in spring or in autumn, particularly in March and November. Downwards to the massif's foot, snowstorm is exclusively a winter phenomenon acting through moderate wind speeds (6-10 m/s).

The *maximum annual number of days with snowstorm* is high in the alpine level (83, in 1987, at Omu Peak weather station) and lower with altitude decrease (36, in 1985, at Bâlea Lake weather station, 4 days with snowstorm at Parâng weather station in 1985 and just one day at the mountain foot at Petroşani weather station) (*Table 2*).

The correlation between the maximum number of days with snowstorm and the altitude allows us to identify the vertical gradient and compute the variation of the number of days with snowstorm at various altitudes (*Figure 7*).

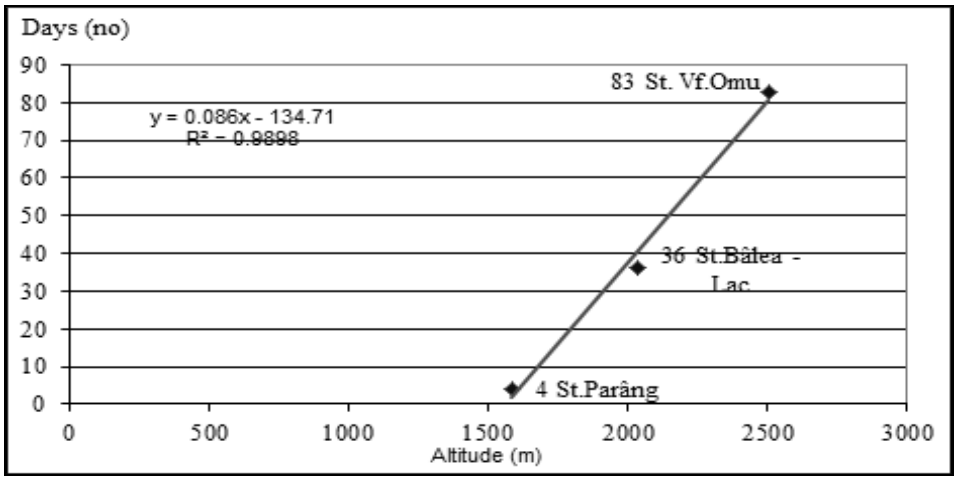

Fig. 7. Correlation between the maximum annual number of days with snowstorm and the altitude

The *intensity of snowstorm* is given by the wind speed (*Figure 8*). Climatic hazards are considered to be those characterized by high speeds of the wind (Bogdan, Niculescu, 1999): *strong snowstorms*, when the wind speed ranges within 11-15 m/s and *violent snowstorms*, when the wind speed overpasses 15 m/s. As regards the characteristics of the wind gusts (Marinică, 2006), those may reach 18-20 m/s (in the case of strong snowstorms) and may largely exceed 20 m/s

(when snowstorms are violent). A third type might be added, having in view that a high mountain area is analysed in this paper, with cases of wind recording speeds higher than 21 m/s that may cause *very violent snowstorms.* On the highest crests of Parâng Mountains very violent snowstorms may well occur (with wind speeds exceeding 20 m/s and reaching even as much as 40 m/s).

At altitudes lower than 2000 m wind speeds may reach 16-20 m/s during a snowstorm event, whereas towards the mountain foot snowstorms act with speeds much smaller than 11 m/s.

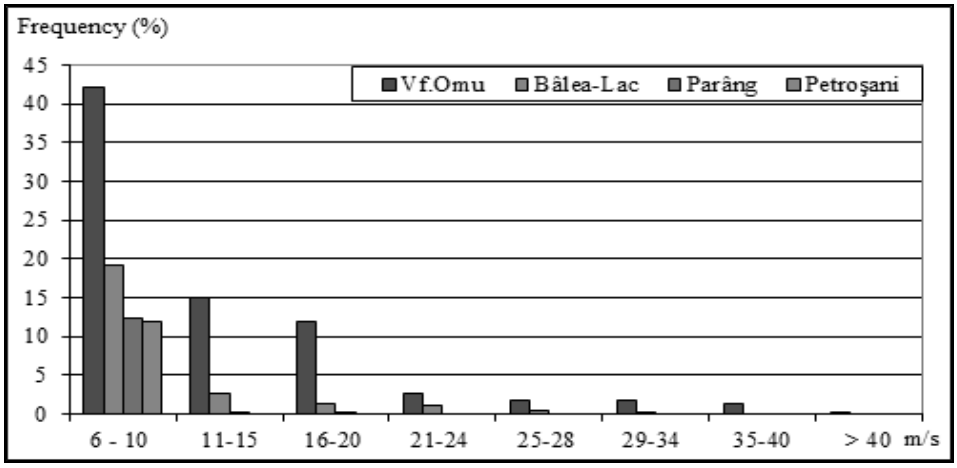

Fig. 8. Variation of annual frequency (%) of cases with wind speeds able to generate snowstorm

After having computed the variation of the vertical gradient of the maximum number of days with snowstorm, taking into account the frequency of the annual occurrence of the snowstorm phenomenon and the wind speed intensity, we determined the snowstorm-likeliness classes for Parâng Mountains (*Table 3*).

Table 3

Snowstorm-likeliness classes in Parâng Mountains

Likeliness classes	Distribution by altitude	N- max. no. of days with snowstorm	Maximum wind intensity (m/s)	F – annual frequency of phenomenon (%)
Very high	> 2200 m	> 50 days	29 – 34 m/s… > 40 m/s	> 20 %
High	1800-2200 m	20.1 – 50 days	25 – 28 m/s	5 – 20 %
Average	1200-1800 m	1.1 – 20 days	16 – 20 m/s	1 – 5 %
Low	< 1200 m	< 1 day	6 – 10 m/s	< 1 %

Through integrating in the Geographic Information Systems the human elements within the area of Parâng Mountains (considered hazardous elements) and through correlating them with the likeliness areas the snowstorm-vulnerability map was obtained for the studied area (*Figure 9*). Very high vulnerability is recorded in the alpine level, where blizzard occurs with the highest frequency and the mountain crest tourist route is very much used by tourists. Low vulnerability is recorded at altitudes under 1200 m, where, although human elements are present to a high extent, snowstorms occur with a low frequency.

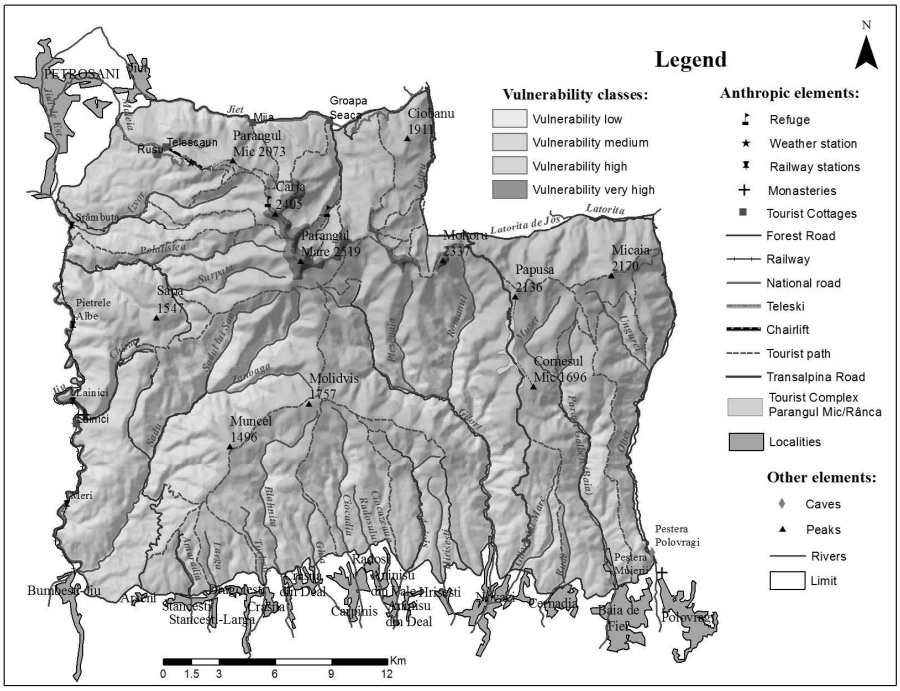

Fig. 9. *Parâng Mountains – Map of the vulnerability to snowstorm*

4. Hazard Aspects. Snowstorm Impact on the Environment and Population

For snowstorm to become a hazard phenomenon, it must meet certain conditions. Given that it is a phenomenon essentially characteristic to the winter season, snowstorm must be accompanied by winds at very high speeds and abundant snowfalls or must occur outside its typical season (either very early or very late, in the extra-season).

During a snowstorm event, visibility decreases very much, which makes concomitant snow falling impossible to assess, this being a winter-specific phenomenon with consequences of the most severe but also very spectacular (Ciulache, Ionac, 1995).

All types of snowstorm (strong, violent or very violent), accompanied by massive snowfalls determine the formation of a 50-100 cm-deep snow layer and snow heaps 1-2 m deep or even more, which causes unbalance in the environment and human victims among those taken by surprise by the phenomenon. In such situations the wind speed makes the human's body temperature decrease fast and intense, this effect being called Wind Chill, (Marinică, 2006), defined as the temperature felt by the human body at a certain wind speed.

That means that not any snowstorm may be considered a climatic hazard phenomenon. Moderate snowstorms, for instance, during which the newly fallen snow is drifted by winds weaker than 10 m/s are not considered climatic hazards. Such moderate snowstorm events drift the fresh snow, leaving the rock exposed to freezing (if such a phenomenon occurs in the extra-season, especially early in autumn, the snow amount is likely to be small, the rock is thus subjected to intense freezing-thawing cycles) and accumulating the snow in sheltered places.

In Parâng Mountains, besides the problems posed to tourists, snowstorm often renders road traffic difficult, especially along the 67C National Road, between Novaci and Rânca. Massive snowfalls and snowstorm caused numerous traffic congestions in one or both traffic directions (*Table 4*), which surprised and blocked tourists climbing towards Rânca resort (*Figure 10*).

Table 4

Traffic congestions along 67 C National Road, between Novaci and Rânca, caused by massive snowfalls and snowstorm in 2006-2007

No.	Date and time of phenomenon occurrence	Effects of phenomenon	Acting from... – to...
1.	19.012006, 18:45	Traffic stopped in both directions	Km 16 – 34
2.	30.01.2006, 09:30	Traffic stopped in one direction	Km 24 – 34
3.	24.02.2006, 11:10	Traffic stopped in both directions	Km 24 – 34-400
4.	3.03.2006, 16:10	Traffic stopped in both directions	Km 16 – 34
5.	4.03.2006, 20:15	Traffic stopped in both directions	Km 26+500 – 34
6.	5.03.2006, 09:00	Traffic stopped in one direction	Km 24 – 34
7.	5.03.2006, 16:20	Traffic stopped in both directions	Km 33+500 – 34
8.	5.03.2006, 21:00	Traffic stopped in both directions	Km 33+500 – 34
9.	13.03.2006, 07:45	Traffic stopped in both directions	Km 24 – 34
10.	13.03.2006, 11:10	Traffic stopped in both directions	Km 24 – 34
11.	3.01.2007, 09:20	Traffic stopped in both directions	Km 22 – 34
12.	3.01. 2007, 11:40	Traffic stopped in both directions	Km 27 – 34
13.	4.01.2007, 04:40	Traffic stopped in both directions	Km 27 – 34
14.	4.01.2007, 11:15	Traffic stopped in one direction	Km 27 – 34

15.	28.01.2007	Traffic stopped in one direction	Km 25 – 29
16.	29.01.2007, 04:30	Traffic stopped in both directions	Km 16 – 34
17.	29.01.2007, 10:00	Traffic stopped in both directions	Km 16 – 34
18.	30.01.2007, 04:26	Traffic stopped in both directions	Km 16 – 34
19.	30.01.2007, 16:30	Traffic stopped in one direction	Km 32 – 34
20.	2.02.2007, 04:15	Traffic stopped in one direction	Km 16 – 34

* data processed from the Archive of the Gorj County Inspectorate for Emergency Situations.

Petroşani public Mountain Rescue Service intervened on 31.08.1986 to save two radio amateur tourists caught by low temperatures, with strong wind, snowfall and snowstorm on Cârja summit (2405 m), where they had put up their tents. Tourists were wearing summer outfits as their tent was torn apart by the rough wind and the snowstorm. They were found by the mountain rescuers and brought back to the mountain foot safely.

The situation was not at all the same on 10.09.1987, when three well-equipped youngsters (two boys and a girl) attempted to complete the crest route and were caught by severe freezing, with snowstorm and massive snow falls (almost half a meter deep, the first layer that year). The youngsters were found dead along the crest path, first the boys, (500-600 m apart), then the girl, after two days of searching, in the area of Mohoru peak.

Fig. 10. Hampered traffic and automobiles blocked by snowstorm and frost on Transalpina road, towards Rânca

5. Conclusions

Snowstorm is a weather phenomenon with permanent occurrence in Parâng Mountains environment at various frequencies and intensities, thus being specific to this mountain massif, with the likelihood of inducing significant risks. Snowstorm affects both population and infrastructure, especially in its extra-season, whereas in the winter months it acts highly frequently and intensely.

The biggest problems are reported in the alpine level, along the tourist routes accessed by tourists and along Transalpina highway, mostly between the settlement of Novaci and Rânca resort.

The latest mentioned resort has developed significantly in the last years and has improved its tourist offer with new ski tracks, which has increased the number of winter sports lovers visiting it.

The number of tourists heading towards Rânca resort has consequently also increased and not all the involved automobiles are properly equipped for the winter conditions there. It must not be overlooked that in snowstorm situations visibility is very low, the traffic is often discontinued or cars remain stuck in the snow. In the last years, snowstorms have killed people in the tourist areas within the alpine level and have created chaos in traffic, fully proving its hazard features.

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