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THUNDERSTORMS PHENOMENA IN THE PRAHOVA'S CORRIDOR, OUTSTANDING CLIMATIC HAZARDS

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ABSTRACT. Thunderstorms phenomena in the Prahova's Corridor, outstanding climatic hazards. Due to the varied topography of land looked, thunderstorms activity presents an uneven distribution, as evidenced by the number of days with thunderstorms phenomena, accompanied by thunder. For this study we used data from observations during 1961-2007 effectual five meteorological stations in Prahova's Corridor and surrounding region with a different location in terms of landscape and local conditions.

1. Introduction

Thunderstorms phenomena are sudden downloads of atmospheric electricity which is manifested by a short and intense light (flash) and by a snap or a hollow roar (thunder), occurring mostly during the warm season.

The *lightning* is a luminous manifestation accompanying a sudden discharge of atmospheric electricity. This download can go from a cloud or may occur within the cloud, but sometimes it can be triggered by tall buildings or on mountain tops.

There are three types of lightning: *ground discharges* (lightning) - they form a huge spark between the cloud and the ground, forming branches pointing downward (Fig. 1) that follows a clearly outlined main channel (in line or tape flash); *internal discharges* (lightning in cloth) – thunderstorms that occur within the cloud and are manifested by a diffuse light inside of which is not possible to identify a channel net channel.

In this category are included „*heath lightning*", which consist of diffuse sparks observed at the horizon; *atmospheric discharges (linear lightning)* can be observed in the shape of a sinuous discharge, often ramified, leaving a cloud of thunderstorms, without touching the earth. Even more, the lightning follows a well defined channel, which consists of a relatively long and approximately horizontal part.

The thunder is the hollow sound or dull crash which accompanies the lightning.

Studies have shown that if, in plain regions, on the passing of thunderstorms forming clouds, the vertical gradient of electric potential exceeds

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10 000 V/m, on mountain heights, it has higher values. The enormous electromagnetic force of thunderstorms forming clouds is given by the dynamic energy conversion of air currents, plus the energy released during condensation of water vapor in the cloud formation processes (water contained in a single Cumulonimbus cloud has a few hundred thousand tons, and in the condensation process, each gram of water yields 600 calories) (Gaceu, 2005).

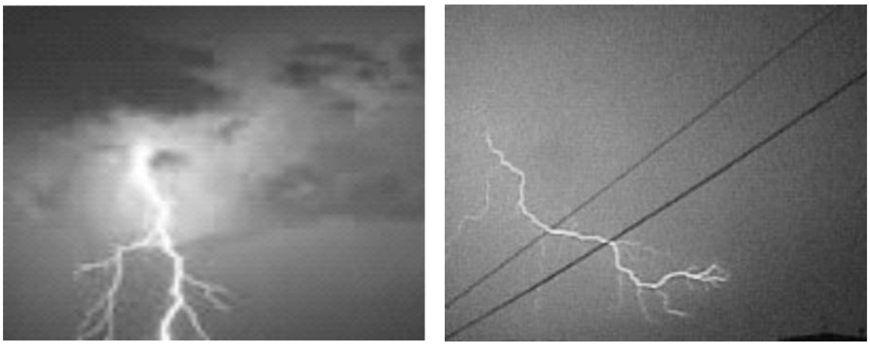

Fig. 1. Thunderstorm phenomena

At the same time, lightning are directed to locations where the electrical conductivity of the land is higher, intensifying above ground pool, with low vegetation or decreasing above the smaller surfaces of lakes, rivers and forests.

2. Thunderstorms phenomena classification

Depending on the nature of the generating impulse, there are *three types of thunderstorms phenomena: intermasic thunderstorm or sunstroke phenomena (thermal or local), frontal thunderstorm phenomena and orographic thunderstorm phenomena.*

▪ *Intermasic thunderstorm or sunstroke phenomena* typically occur during hot summer afternoons, last shortly, have low intensity and are distributed unevenly on the territory.

Fig. 2. Precipitation generating *Cumulonimbus* clouds

These are formed inside cold air masses which, when reaching in the summer overheated terrestrial surfaces, are unstabilized by ascending convection currents (caused by the overheated active surface) leading to the formation of *Cumulonimbus* clouds (Fig. 2).

Such thunderstorms pheno-mena present a cellular structure composed of an *ascending current*, which is associated with a *descending current* and have *three developing stages*, corresponding to those of Cumulonimbus cloud:

– *the evolution stage* (*Cumulus* cloud with a thickness of about 5 km), in which *prevail ascending currents*;

– *the maturity stage* – when the cell contains an *ascending* current, which determines the Columbus cloud growth, to about 10-12 km, and a *descending one*, which spreads sidewise and becomes cold when touching the ground, causing the air to cool and increasing the intensity of the wind, heavy rains and sometimes even rain storms;

– *the scattering or dissipating stage* - is reached when descending currents prevail, and the ascending ones have stopped. The top of the Cumulonimbus cloud is flattened and takes the shape of an anvil, and then it gradually begins to unravel. Rain is reduced, descending currents become weaker, and the Cumulonimbus cloud is fragmented, so that from its top compact masses of cirrus clouds are detached, and from its lower part, *Stratocumulus* or *Altocumulus* clouds.

▪ *Frontal thunderstorms phenomena* may occur in any season, both during the day and night, and in comparison with intermasic or sunstroke thunderstorms phenomena, they are more intense and last longer. These are determined, in general, by the activity of the cold front, as a result of the violent displacement of warm, humid air that is forced to rise above the cold one, moving in the direction and speed of the above.

In the summer, thunderstorms phenomena can be encountered even inside the Nimbostratus-Altostratus clouds system (whose multilayered appearance gains a *Cumulonimbus* character) due to warm front, where the warm, unstable air, rises above the cold air, which regress, but these are less common than cold front thunderstorms.

▪ *Orographic thunderstorms phenomena* occur especially during the warm season, when, due to the thermal contrast created between the warm, Mediterranean air entering the Pannonian Lowland and the cold air, from the higher adjacent regions, causes barrel depressions of orographic origin with restricted areas, that become very active if in the altitude has been a wet and cold air advection of polar origin. These types of thunderstorms are caused by the increasing of ascending turbulent motions of moist air on the slopes of hills and mountains exposed to air masses advection.

3. The genetic causes of thunderstorms phenomena

The main genetic factor producing thunderstorms phenomena lais in the general circulation of the atmosphere, which in interaction with solar radiation and local geographical conditions, creates aerosinoptic situations favorable for their occurrence. Thunderstorms activity develops most often in cases with low atmospheric pressure and low barrel gradients.

Thunderstorms phenomena arise due to the strong heating of air masses, depending on their direction of travel. To form, thunderstorms require warm air, because this alone may contain large amounts of water. Besides the large amount of water vapors, there must be present high temperatures and sunstroke must be strong so that they trigger the ascending movement of air, leading to the formation of *Cumulonimbus* clouds.

As noted above, in addition to the general circulation of air masses, an important role in producing thunderstorms phenomena belongs to the the particularities of the active surface. These favor or diminish the production of convection currents, leading to the formation of *Cumulonimbus* clouds and contribute to regional differences that occur in the spatial distribution of thunderstorms phenomena.

A genetic factor of thunderstorms phenomena is represented by *the local air circulation* too, in the form of *breezes*. Valley's ascending movements stimulate during the day time, to the heights, hotter and more humid air from the valleys, increasing cloudiness in the hills, which often generates strong thunderstorms phenomena.

4. Territorial distribution of the annual average number of days with thunderstorms phenomena

Prahova's Corridor relief, through its massiveness and altitude, contribute to the emergence and development of thunderstorms phenomena. Air masses ascend the heights and enhance the condensation of water vapors, clouds become thickened, and on the peaks the outbreaks of thunderstorms activity are localized.

The climatic parameter owning an essential role in defining the climate and most importantly of the climatic hazards characteristic during the warm season, thunderstorms phenomena are developing in the Prahova's Corridor and throughout its surrounding regions, a relatively uniform territorial distribution, up to about 1500 m altitude, as indicated by the inverse correlation with altitude, of the annual average number of days with thunderstorms phenomena, according to the polynomial equation of degree 3, of the form:

$y = -\ 0.00000000344199x^3 + 0.00001376529303x^2 - 0.01484359290110x + 44.13351810462690$; where:

y – represents the multiannual average number of days with thunderstorms phenomena;

x – the grid of the analyzed region.

The territorial distribution map of multiannual average number of days with thunderstorms phenomena has been developed using the *Raster Calculator* function from the module of spatial analysis, *Spatial Analyst*, ArcGIS 9.2 program. Following the introduction of this equation in the *Raster Calculator* function and overlapping the grid over the region, has resulted a number *of three valoric classes* (Fig. 3).

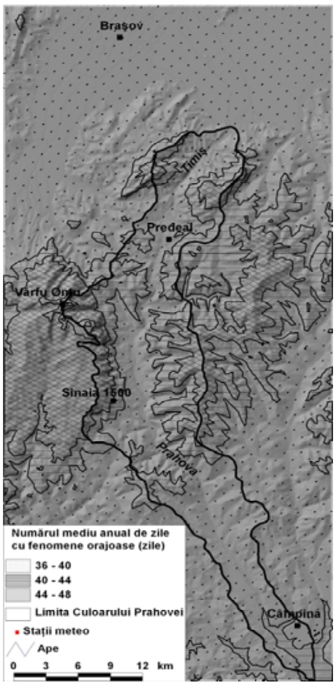

Fig. 3. Territorial distribution of the annual average number of days with thunderstorms phenomena in Prahova's Corridor and its surrounding regions

Therefore, *the first class of values,* between 36-40 days per year with thunderstorms phenomena is characteristic of all sub-Carpathian area, besides its southern tip along the Prahova's Valley and from its confluence with the river Doftana, as well as some small areas in its the north-west region.

At the same time it can be noticed that this class of values has the largest expansion in the Prahova's Corridor in the Timiş Valley, the Timiş Depression, Clăbucetele Predealului (except its west side), Sinaia Depression and Bucegi Plateau, at over 2500 m altitude, but also in its surrounding region in the south-west, from north (Braşov Depression) and along the Doftana's Valley.

The second class of values, between 40-44 days per year with thunderstorms phenomena is characteristic of eastern and western slopes of the Massif Postăvaru and of the Piatra Mare, which look to the Prahova Valley, western and eastern slopes Clăbucetelor Predealului, the west of Baiu Mountains, in contact with the Sinaia Depression and the eastern side of the Prahova scarp, to the Prahova's Valley.

The third class of values, between 44-48 days per year with thunderstorms events includes the largest number of days with thunderstorms phenomena. This area can be found in the perimeter of Sinaia weather station 1500, on Mount Furnica, in the Jepii Mari şi Jepii Mici Mountains, on the Caraiman Mountain as well as in the Cerbului Valley and in smaller areas of the Baiu Mountains, Piatra Mare and Postăvaru Massives (Fig. 3).

A series of regional and local characteristics of thunderstorms phenomena in the territory of Prahova's Corridor and its surrounding region result from the analysis of their specific parameters.

5. The main para-meters of thunderstorms phenomena

▪ **The average annual number of days with thunderstorms phenomena.** Are recording a slight increase, concurrent with the altitude increase, to about 1500 m, after which it begins to decrease to about 2500 m altitude, due to lower temperatures.

Therefore, while thoughout the subcarpathian sector (Câmpina station) and the Carpathian one (Predeal station) are being recorded the same average annual number of days with thunderstorms phenomena (39.9 days/year), at altitudes above 2500 m (station Peak Omu), the average annual number of days with thunderstorms phenomena decreases by 0.7 days/year (39.2 days/year) (Fig. 4).

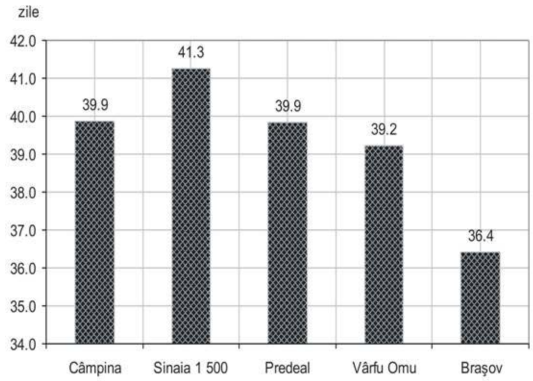

Fig. 4. The average annual number of days with thunderstorms phenomena

The extremes belong to the Sinaia 1500 weather stations (which present the largest average annual number of days with thunderstorms - 41.3 days / year) and Braşov (with the lowest annual average number of days with thunderstorms – 36.4 days / year).

Monthly average number of days with thunderstorms phenomena. During the year, most days with thunderstorms phenomena occur within warm season from April to September, especially during June and July, when there are meet the most favorable conditions for development of thermal convection and the formation of *Cumulonimbus* clouds. They vary between 9.2 days/year in the region adjacent to the Prahova's Corridor (Braşov) and 10.5 days/year at altitudes > 1500 m (Sinaia 1500 m).

The month of the most common thunderstorms phenomena is *June*, for four of the five stations studied, except for the Braşov station, located adjacent to Prahova's Corridor, where most days with thunderstorms phenomena do not occur in the months of summer solstice (June), but in *July* (9.2 days), when thermal convection develops best and when throughout our country the Azores Anticyclone and the Middle East Depression act, so that the movement is north-west to south-east (ocean), resulting in a wet, rich in precipitation weather.

Also, in Predeal station, most days with thunderstorms phenomena occur in both summer months, in equal percentage (9.9 days). Maximum monthly value is recorded at over 1500 m altitude (10.5 days in Sinaia 1500), being favored by the presence of the first level of condensation.

Numerous thunderstorms phenomena also occur during *July* and *August*, with the same genetic causes (between 7.3 days per year at Câmpina and Braşov in *August* and 7.8 days in Sinaia 1500 m during the same month). In *July*, the frequency of days with thunderstorms phenomena ranges from 9.2 days to 9.9 days in Braşov and Predeal.

Beginning with September, the activity of thunderstorms is diminished. The rare thunderstorms phenomena occurring in *September* or *October* (0.5-2.5 days) are generated by the presence of atmospheric fronts between cyclones and the maximum barrel from the Atlantic Ocean and the Eastern European one.

Between *November* to *March*, thunderstorms phenomena are exceptions; they are possible only because of sudden replacement of a tropical air mass with cold polar air, and in the case of weather stations located at altitudes < 2500 m, they are completely missing between *December* and *January* (Predeal), *January-February* (Braşov) and the first month of the year at Sinaia 1500 m and Câmpina (Fig. 5).

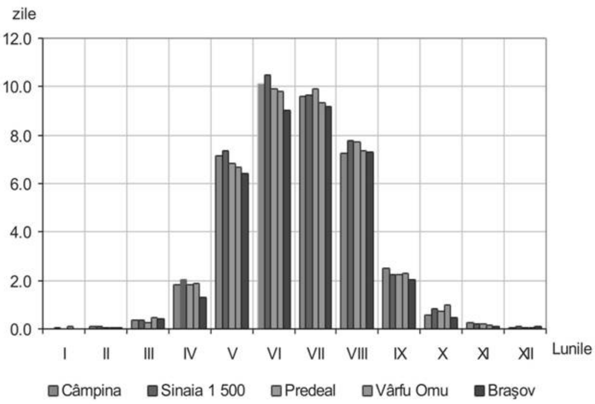

Fig. 5. Monthly average number of days with thunderstorms phenomena

Maximum number of days of annual thunderstorms phenomena. During the 47 years analyzed, the year of 1975 can be noticed, when on the Prahova's Corridor territory has been recorded the maximum annual number of days with thunderstorms phenomena at all five stations considered.

Compared to the average annual number of days with thunderstorms phenomena dependent on the intensity of frontal activity, the maximum annual number of such events can exceed average cases by 50-60%.

In the Prahova's Corridor, the maximum annual number of days with thunderstorms events decreases day by day, with the increasing of the altitude, from 77.0 days at Câmpina to 76.0 even days in Predeal and even to 75.0 days at Omu Peak.

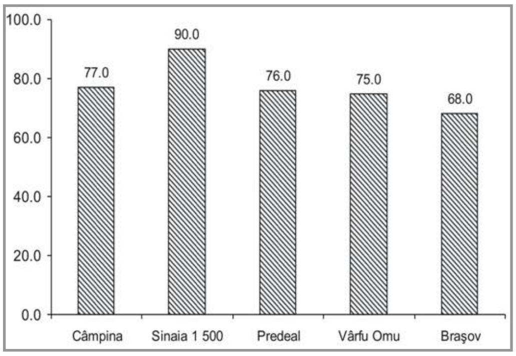

Fig. 6. The maximum annual number of days with thunderstorms events

As with the annual average number of days with thunderstorms phenomena, a different situation is found in the weather stations of Braşov and Sinaia 1500, each with 90.0 days and 68.0 days of thunderstorms (Fig. 6).

Also, ***the maximum number of days per month with thunderstorms***

phenomena may exceed by 13 to 23 cases, in June-July, being more numerous by 10 days, compared to the average situation.

The annual favorable range of phenomena thunderstorms production. Regarding the driving factors, the intensity and frequency of cyclonic activity and the invasion of humid air, the year interval favorable to the production of thunderstorms phenomena (the time between the beginning and end of auditory and visual reported thunderstorms phenomena) varies from one sector to another. *The beginning of the average annual interval* with thunderstorms phenomena is directly related to the frontal activity, to the cyclones entering the Romanian territory laden with moist air masses, leading to the formation of *Cumulonimbus* clouds.

In this case, the earliest date starting the interval with such phenomenon is placed at the beginning of the year (*February*), for stations located at altitudes < 2500 m, because in case of Peak Omu station, situated at over 2500 m altitude, this phenomenon is possible in any month of the year.

The annual interval in which thunderstorms phenomena can be produced varies between *February* to *December,* in case of Câmpina and Sinaia 1500 stations, from *February* to *November* in Predeal and from *March* to *December*, in Braşov.

The end of the average annual interval with thunderstorms phenomena has the same uneven territorial distribution as the beginning of this range. Depending on the frequency and intensity of cyclonic activity, the annual range with thunderstorms phenomena can end in the first or second month of winter in Câmpina, Predeal, Sinaia 1500 and Braşov, but may extend throughout the entire year (Omu Peak).

▪ **Favorable daily range for thunderstorms production.** Analyzing the average of hourly values for the duration of thunderstorms it is found that they have reduced duration and frequency durring night time and early morning hours, when the air thermal stability is higher than in day at noon.

In the daily variation of these phenomena, the lowest values are recorded in the last part of the night and in the first part of the morning (between 5^{00}-9^{00} in the Carpathians and respectively between 5^{00}-10^{00} in the sub-Carpathians) and the highest values, in the afternoon hours (in the 13^{00}-16^{00} timeframe in the mountains, and 14^{00}-17^{00} on the hills), when thermal convection is maximum.

▪ **Duration of thunderstorms phenomena.** It highlights the influence of physico-geographical conditions on the production and evolution of thunderstorms phenomena.

Therefore, in the *mountains of Prahova's Corridor* at an altitude > 1500 m, thunderstorms phenomena duration has the highest values (over 120 hours per year), being driven by increasing frontal activity and thermoconvector processes. In contrast, on the highest peaks (> 2500 m altitude) thunderstorms phenomena duration is lower (under 100 hours per year) due to lower temperatures and reduced humidity.

At the same time, inside depressions, the duration of thunderstorms phenomena is about 30-40 hours less than the surrounding mountain slopes. Such reduction can be seen in all areas of the depression, as a result of the descent of air and its adiabatic heating. At the same time on the slopes oriented towards west and north, the thunderstorms phenomena duration is higher than in the east. In Braşov Depression, the short duration of thunderstorms phenomena (between 50-70 hours) is due to temperature inversions in particular. The average daily duration of thunderstorms phenomena in the territory of Prahova's Corridor varies between about 2.0 and 3.7 hours.

6. Annual and monthly frequency by value classes of thunderstorms phenomena

To complete the characterization of thunderstorms phenomena spreading, we determined the percentage frequency or probability of their occurence, after Grissollet, Guilmet and Arléry, 1962 (Mic, 2010).

▪ **Frequency by value classes of the average annual number of days with thunderstorms phenomena**. Compared with the other two climatic hazards typical during the warm season (torrential rain and hail), which may occur on the territory of Prahova's Corridor (Table 1), in the case of annual values of thunderstorms phenomena, *the highest probability* of producing belongs to the *third class of values* (38.0 ... 48.4) (37.0%), followed closely by the *second class of values* (27.5 ... 37.9) (34.0%).

The *first class of values* (17.0 ... 27.4) has a rate of only 12.3% and within it, the Sinaia 1500 and Predeal stations, each have four years, respectively 1.7%. Also, in the case of Sinaia 1500 and Predeal weather stations, of the four years belonging to each station separately, the first class of values occurs in two years (1992-1993) and three consecutive years (1996-1998).

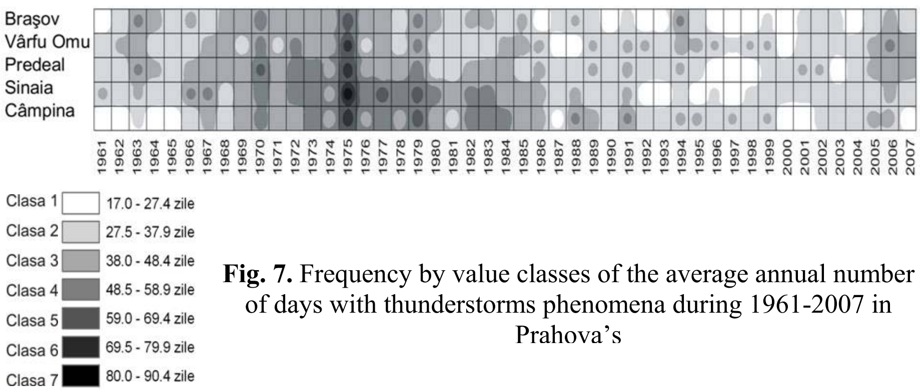

Fig. 7. Frequency by value classes of the average annual number of days with thunderstorms phenomena during 1961-2007 in Prahova's

The *fourth class of values* has a more compact character, like the first class of values, where four years belong to each of the stations Predeal, Braşov and Peak Omu (1.7%).

The fifth, sixth and seventh classes are poorly represented, with the lower probability of production (2.1…0.4%) (Fig. 7).

▪ **Frequency by value classes of the average monthly number of days with thunderstorms phenomena**. Unlike the average annual number of days with thunderstorms phenomena, in the average monthly number of days with thunderstorms phenomena, the higher probability of production belongs to the first class of values, in the percentage of 60%: 66.7% (Câmpina), 64.9% (Sinaia 1500 m), 63.3% (Braşov), 61.2% (Predeal), 60.6% (Omu Peak).

Also, the smallest probability of production belongs to the seventh class of values, whose percentage is subunitary: Predeal (0.9%), Câmpina (0.7%), Sinaia 1 500 and Braşov 1500 (0.4%); the only exception is the Omu Peak station (1.1%), situated at an altitude of over 2500 m (Fig. 8).

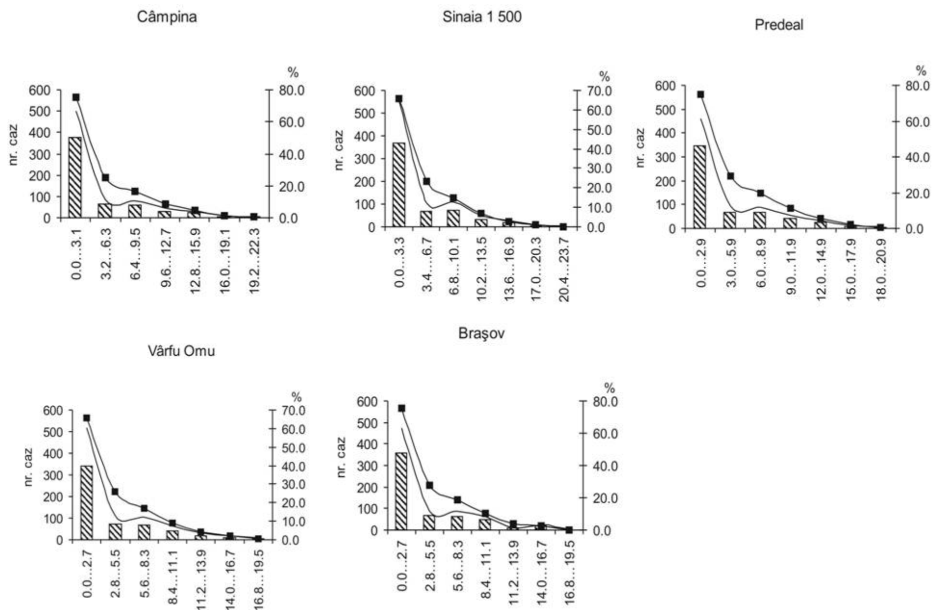

Fig. 8. Frequency by value classes of the average monthly number of days with thunderstorms phenomena

7. Conclusions

Thunderstorms phenomena usually accompaniate rain showers, heavy hailand falls and even storms. In this complex context of production, the degree of hazard in thunderstorms phenomena increase, and the damage caused by lightning joins those of hail (large and very dense hailstone), and of the strong wind (which produces trees falls).

Throughout the twentieth century, especially in the 9 and 10 decades until the first years of the XXIst century, along with the increasing of global warming, an increase in the general circulation of the atmosphere has occured, generating extreme climatic phenomena, and among these, the thunderstorms phenomena.

Therefore, especially after the year 2000, both the Prahova's Corridor and its surrounding region (Braşov Depression) were marked by a series of thunderstorms phenomena. They have caused in many situations invaluable damages in the power systems and telecommunications, animal death and even casualties. All these phenomena lead us to include *thunderstorms phenomena in the risk climate events category*.

We note the particularly dangerous thunderstorms phenomena produced on ***24.06.2003*** in ***Ghimbav*** city and in Braşov , which mainly affected the power lines in these localities. Also, the thunderstorm was accompanied by a particularly strong heavy rain, and the determined accumulated amount of rain created road blocks on DN1 and DN73 A, linking Râşnov to Predeal.

Another particularly dangerous thunderstorm phenomenon occurred on ***21.07.2007***, in ***Ghimbav*** city, following which, three people died stoked by lightning (Inspectorate for Emergency Situations „Ţara Bârsei", Braşov).

In the Prahova's Corridor, on ***18.08.2008***, thunderstorms phenomena caused by the Mediterranean cyclone's activity have mainly affected the city of ***Buşteni***. These have lasted a quarter of an hour, during which time the center of Buşteni was completely paralyzed. The thunderstorm was accompanied by a heavy rain with stones, which began suddenly, with strong thunders and lightning, and the air temperature dropped sharply from 20°C to +10ºC. After the thunderstorm, the sky cleared and in the north-east appeared a double rainbow, behind which the city of Predeal could be seen.

From the facts presented it may be noted that regional differences in thunderstorms activity occur in the Prahova's Corridor, the main influence being of the topography exposure and local conditions.

Naturally, not all thunderstorms phenomena have serious consequences on socio-economic areas, either because they are not very extensive, either because the affected region is not too large or populated, but their study is particularly important because it provides the ability to restore thunderstorms activity in time and space, thus contributing to a better understanding of the phenomenon in order to take measures preventing human loss or material damage.

In conclusion, it may be noted that the both duration and the other parameters that characterize the thunderstorms phenomena have a territorial division that reflects the complex interplay of thir genetic factors, whom action is differently nuanced in the analized space.

An evaluation of thunderstorms phenomena based on the Bryant criterion (1991), in the Prahova's Corridor (Table 1) highlights the fact that these are ranked on the 3rd position in the hierarchy of climatic hazards characteristic to the warm season, with an average of 3.0 by region, which indicates an *average vulnerability of the analyzed territory to this type of climate hazards* (Croitoru, Moldovan, 2008).

Table 1. The hierarchy of specific climatic hazards during the warm season depending on the characteristics and impact in the Prahova's Corridor

Number of hierarchy	Phenomenon of climate risk	Gradation characteristics and impacts number of hierarchy									
		1	2	3	4	5	6	7	8	9	Average
1.	Torrential rains	3	3	3	4	1	1	3	1	2	2.3
2.	Hail	3	3	3	5	2	3	2	1	2	2.7
3.	Thunderstorms phenomena	3	5	3	4	3	5	1	1	2	3.0

Legend

Gradation characteristics and impacts: 1. Severity; 2. Durations; 3. Total afected area; 4. Total human loss; 5. Total economic loss; 6. Long term effect; 7. Suddeness; 8. Occurence of associated phenomena; 9. Occurence frequency.

We conclude, considering that by switching to automatic measurements (from 11.01.1999, at the meteorological station of Predeal, and respectively, 04.10.2002, at Sinaia 1500 – a station that also records, as shown in the stated material the highest average annual number of days with thunderstorms phenomena), with stations equipped with specialized sensors, Vaisala Milos type, the damage caused by this type of climatic hazard has been reduced, through timely submission to the forecast centers of possible outbreaks of thunderstorms.

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