Analele Universităţii din Oradea, Seria Geografie, Tom XIX, 2009, pag. 71-77

THE CHARACTERISTICS OF THE FROST AND HOARFROST PHENOMENA IN THE APUSENI MOUNTAINS AREA

Ovidiu GACEU[1]

Abstract: ***The Characteristics of the Frost and Hoarfrost Phenomena in the Apuseni Mountains Area.*** The present paper shows the characteristics of the frost and hoarfrost phenomena in the Apuseni Mountains based on data collected between 1961 - 2000, measured at nine meteo stations located in the Apuseni Mountains area. Data have been processed in accordance with the standard methodology used in the climatological practice, by calculating the main climatic parameters of these phenomena: the average data when the first and last frost and hoarfrost appear, the average duration of the period with or without frost and hoarfrost, as well as the extreme data regarding the appearance of frost and hoarfrost. The values, presented in the charts, have been assessed accordingly, and the results have been presented synthetically in the conclusions.

Key words: frost, hoarfrost, parameters, the Apuseni Mountains

1. Introduction

Frost and hoarfrost are meteorological phenomena habitual for the climate of the Apuseni Mountains. Between frost and hoarfrost phenomena there is a close relation due to the fact that hoarfrost appears when frost appears, it is an effect of frost, whilst frost phenomenon does not always imply hoarfrost.

The most favourable conditions of hoarfrost appearance are the anticyclonic conditions, characterized by air temperatures ranging between –2 and –3^{0}C, calm weather or mild wind (< 2m/s), relative humidity over 80%, thin clouds or clear sky, high solarization during daytime and high effective radiation at night which determines the fall of temperature below freezing and the sublimation of the water vapours inside the ground layer of inversion. Hoarfrost deposits in larger amounts on the upper surfaces, slightly oblique, of the flat things (leaves, planks, roofs) situated near sources of humidity (lakes, swamps etc.). If the radiative cooling is strong, hoarfrost deposits around air conductors, but having a bigger thickness on their upper parts and a smaller one on the lower parts. Deposition is even more reduced if the respective conductor is thinner. For instance, on conductors of 5 mm in diameter, the thickness of the hoarfrost layer gets up to 2-3 mm, whilst on conductors of 0,5 mm in diameter there is hardly hoarfrost or in small quantity (Ciulache, Ionac, 1995).

2. Definition of the frost and hoarfrost phenomena

By *frost*, we understand the period of time within a day , when air or ground temperature gets for a moment or several hours below 0^{0}C. If the air temperature is negative all day (24 hours), frost is permanent, continuous and such a day is called winter day (Topor, 1958).

Hoarfrost is the meteorological phenomenon that appears on the ground or on the

[1]University of Oradea, Faculty of History, Geography and International Relations, Department of Geography, Tourism and Territorial Planning, Center of Research and Territorial Analyses, No. 1 University Street, Oradea, Bihor, România, gaceu@yahoo.com

ground things under the form of whitish ice crystals, usually in the shape of scales, pins, feathers or fans. It occurs at night time or in the morning before sunrise, on calm and cool weather, in the spring, autumn and winter, by sublimation of the water vapours from air onto the objects whose temperature falls under 0^0C due to nocturnal radiative cooling (Ciulache, Ionac, 1995).

3. Genetic causes of frost and hoarfrost

Frost and hoarfrost are determined by three categories of causes: *air masses movement, characteristics of the active surface and the characteristics of some meteorological elements (humidity, nebulosity, pressure, wind).*

The first category, *air masses movement,* was minutely studied by Topor (1958), who, by analyzing the data obtained from the meteorological observations over a period of 65 years (1886-1950) and the synoptic charts of daily distribution of the atmospheric phenomena in northern hemisphere, made by the meteo stations from various countries in Europe for the period between 1899-1938, as well as the maps drafted by the Institute of Meteorology between 1928-1955, established the types of cooling which determine the frost and hoarfrost in Romania and their genetical causes.

Topor (1958), Bogdan (1978), Ciulache, Ionac (1995) show that both spring and autumn coolings are determined by polar or arctic air masses and are of three types: advective, radiative and mixed (advective-radiative), the last ones being the most frequent.

The advective coolings are determined by the invasion of polar or arctic air whose temperature is lower than 1^0C, affect large areas, last 1-3 days and are more frequent in the winter, but produce important losses in the first part of spring. R*adiative coolings* are generated by big losses of heat at ground level as a result of radiative emission characteristic to cloudless and calm nights or nights with mild wind. The maximum intensity of the cooling is recorded at nighttime before sunrise, and its intensity and duration are strongly influenced by landform, status of ground surface, air and ground humidity etc. *Mixed coolings (advective-radiative)* occur as a result of the invasion of cold air, but with positive temperatures, from upper levels which continue to cool down through nocturnal radiative cooling up to $-4 \div 6^0$C, even though it was 20^0C at daytime.

Beside the afore mentioned synoptic processes, the occurrence of frost and hoarfrost is determined by the *characteristics of the active surface:*

– *relief fragmentation* favours the earlier occurrence and the later disappearance of the frost, and in the period of possible frost occurrence, it determines a higher daily and seasonally frequency;
– *landforms,* especially depressions, valley lanes and longer valleys, in which the cold air flows off the versants, favours the advections of cold air and the occurrence of earliest and latest frosts;
– *the positionig of the versants* as opposed to the advection of air masses and solar radiation determines a different repartition of the frost: the western slopes situated in the way of the air masses get frost and hoarfrost, whereas the eastern ones which are sheltered don't get frost. In the case of the western slopes, the air being forced to go up the slopes, cools down by adiabatical relaxation, and on the opposite side, it descends and warms up by adiabatical compression;
– *crests, peaks, saddles, upsaddles,* as landforms of altitude permanently subject to atmospheric ventilation, face earlier and more persistent frosts, sometimes all year round;
– *in the meadows of big rivers,* frost and hoarfrost occur later and are less frequent due to limitary water surfaces, whereas *in the meadows of small rivers* in the fragmented areas where the cold air flows into valleys, with increased humidity,

the frequency of such phenomena is higher;
– *the natural vegetable layer*, especially the forests having the role of a barrier and thermic regulator, slows down and reduces the frequency of frost phenomenon;
– *the colour and the soil degree of humidity* influence the frequency and the intensity of the frost and hoarfrost: the black and dry soil favours an increased frequency, whereas the light-coloured and humid soil diminishes this frequency;
– *the snow layer* contributes to the increase of the radiative cooling on its surface, but maintains a constant temperature, thus having a protective role for plants at its inferior limit (Bogdan, Niculescu, 1999).

The third category of factors favouring the occurrence of frost and hoarfrost is constituted by the pattern of the meteorological elements.
– *the nebulosity of the lower stratiform clouds* prevents the occurrence of frost and hoarfrost, even though there are optimal thermic conditions;
– *the high pressure* favours the occurrence of frost and hoarfrost, due to the the fact that a high baric pattern is associated with less humidity, a less cloudy sky and a higher air transparency;
– *the wind* has a double role: it favours the occurrence of advective frost, increasing the degree of evaporation and consequently, the fall of temperature, on the other hand it prevents the occurrence of radiative frost because it blends the warm air with the cold one;
– *the high humidity* of the air and soil reduces the occurrence of frost and hoarfrost. For example, a humid soil radiates less heat during nighttime than a dry one, and after the rain, even though the temperature is below 0^0C, hoarfrost does not occur either on soil or plants as their temperature is much higher (Topor, 1958).

4. The main parametres characterizing frost and hoarfrost

The parametres characterizing frost and hoarfrost are:
- the average dates of occurrence of the first and last frost, respectively hoarfrost;
- the average duration of the period with or without frost and hoarfrost;
- the extreme dates of occurrence of the frost and hoarfrost.

4.1. The average dates of occurrence of frost and hoarfrost

The average dates of occurrence of frost and hoarfrost vary in time and space, as a result of the external climatic influences superposing the relief of the Apuseni Mountains having an altitudinal disposition in stairs. Thus, *the average date of occurrence of the first frost* is earlier and earlier the higher the altitude gets, the first frost occuring on the highest peaks of the mountains, 8-10.09 at Vlădeasa and Stâna de Vale, “is late” until 3-5.10 at medium altitudes such as the meteo stations at Câmpeni and Băişoara, whereas at the foot of the mountains (Borod, Ştei, Gurahonţ) it occurs in the second half of October, except for Huedin where, as a result of local conditions permitting the flow of the cold air off the north-eastern versant of Vlădeasa, it occurs in the first part of October (chart 1).

As opposed to this, *the average date of occurrence of the last frost* takes place later and later, the higher the altitude gets. Thus, at the foot of the Apuseni Mountains the last frost occurs at an average date in the spring in the second half of April (16-23.04).

Inside the mountains, the last frost occurs later until the beginning of May at Câmpeni and Băişoara (1-8.05), whereas on the highest peaks it occurs latest in the middle of June, respectively 16.06 at Vlădeasa 1800. To be noted that at Stâna de Vale, the last frost occurs approximately one month later than at Băişoara, although Stâna de Vale is located at lower altitudes than Băişoara, this happening because of the flow of cold air off the surrounding versants and its deposition on the depression bed of Stâna de Vale, as well as because of the absence of föhnal movements.

The average and extreme dates of occurrence of the frost and the average duration of the period with or without frost in the air in the Apuseni Mountains

Chart 1

Station	Average date of the		Average period		Extreme dates of frost occurrence	
	first	last	with	without		
	frost		frost		autumn	spring
Gurahonț	22.10	16.04	177	188	01.09	15.05
Ștei	23.10	16.04	176	189	17.09	02.06
Borod	18.10	20.04	185	180	28.09	15.05
Huedin	13.10	23.04	193	172	14.09	15.05
Câmpeni	05.10	01.05	209	156	14.09	02.06
Stâna de Vale	10.09	02.06	266	99	07.08	20.07
Băişoara	03.10	08.05	218	147	08.09	04.06
Vlădeasa 1800	08.09	16.06	282	83	03.08	25.07

Source: data provided by the National Agency of Meteorology Archive

As opposed to ground frost, *hoarfrost can occur in autumn* at the same time with the frost or even later, but never earlier, because in order to occur, the temperature must fall below 0^0C. Furthermore, it can disappear in the spring at the same time with the frost or even earlier, but never after (Topor, 1958; Bogdan, Niculescu, 1999). The same thing can be noticed if one analyzes the air frost and hoarfrost.

The average dates of occurrence of the ground hoarfrost and the average duration of the period with or without hoarfrost in the Apuseni Mountains

Chart 2

Station	Average date of		Average period	
	first	last	with	without
	hoarfrost		hoarfrost	
Gurahonț	15.10	16.04	185	180
Ștei	17.10	16.04	182	183
Borod	06.10	25.04	202	163
Huedin	07.10	25.04	201	164
Câmpeni	06.10	27.04	204	161
Stâna de Vale	24.08	10.06	292	72
Băişoara	22.09	10.05	232	133
Vlădeasa 1400	22.09	30.05	251	114
Vlădeasa 1800	27.09	04.05	220	145

Source: data provided by the National Agency of Meteorology Archive

Comparing data from chart 1 to data in chart 2, one can notice an advance of the average date of hoarfrost occurrence (observed at ground level), to the average date of frost occurrence (observed in the air). This phenomenon is explained by the fact that in the present paper we take into account only the air temperature $\leq 0^0$C measured at the height of 2 m above the ground, because there are no measurements of plants temperature and not all meteo stations measure the ground temperature. It is known that the air temperature measured inside in the morning is higher than the ground temperature, thus hoarfrost occurring on the ground or grass even though the thermometer inside the meteo station indicates temperatures higher than 0^0C. Topor (1958), by analyzing 140 cases when the minimum air temperature was $+1^0$C, shows that the ground minimum temperature was negative in 71% cases, and the hoarfrost occurred on the grass in 84% cases. This explains why at numerous meteo stations in the Apuseni Mountains hoarfrost occurs, as an average date, before the first frost, in autumn, and after the last frost, in the spring.

Analyzing the average dates of hoarfrost occurrence (chart 2) one can notice that it shows the same altitudinal location as frost occurrence and an un-location depending on the local particularities of the active surface, the microrelief, the vegetable layer, the type of soil etc.

4.2. The average duration of the period with or without frost and hoarfrost

The average duration of the period with frost is the period between the average date of frost occurrence in autumn and the average date of its disappearance in the spring. This period depends on the same causes: external climatic influences, altitude and local particularities. *The shortest average duration of the period with frost* is recorded at Ștei and Gurahonț 176-177 days, followed by Borod and Huedin with 185-193 days, as a result of the cold air flow off the mountains versants. The higher the altitude gets, the duration of the period with frost increases, up to 209 days at Câmpeni, 218 days at Băişoara, 266 zile at Stâna de Vale and 282 zile at Vlădeasa 1800 (chart 1).

To be noticed that during this period, the frost is not continuous but possible, the days with frost alternating with days of defrost, thus the influence of frost on the environment has a variable intensity in time and does not always produce changes or instabilites of the environment.

Taking into account the genetic conditions of hoarfrost and the work methodology used, one can notice that the *the average duration of the period with hoarfrost* generally longer with 1-2 weeks than the average duration of frost, for similar reasons that belong to the methodology of calculating these phenomena (ground hoarfrost and air frost). Except for Vlădeasa 1800, where strong frequent winds prevent the occurrence of hoarfrost in some favourable conditions, thus reducing the duration of the hoarfrost period to that of frost (chart 2).

In the period between the two average dates of the first and last frost and hoarfrost, frost and hoarfrost are winter phenomena normal for the climate of the Apuseni Mountains, to which the vegetable layer and the autumn crops that winter, show adequate adjustments. Even in these conditions, the frost and hoarfrost phenomena can become dangerous to crops if winters get extremely frosty, if the snow layer is blown by the wind, if low temperatures maintain for a long period and the local particularities of the active surface accentuates the intensity of the phenomena.

The average duration of the period without frost (hoarfrost) is the period between the average date of the last spring frost (hoarfrost) and the average date of the first autumn frost (hoarfrost). As shown in chart 1, the longest duration of the period without frost is to be found on the western versant (172-189 days), and the shortest, deep inside the mountains, respectively at Stâna de Vale (99 days) and Vlădeasa 1800 (83 days). The average duration of the period without hoarfrost shows a similar pattern of 163-183 days at the foot of the western versant and 72-145 days at medium and higher altitudes, differentially depending on local conditions (chart 2).

4.3. Extreme dates of frost and hoarfrost occurrence

Frost and hoarfrost can produce damage of the economy especially in *off-season,* respectively outside their characteristic period, between the first and last average date of occurrence. These situations can appear in transitory seasons , spring and autumn, due to the earliest autumn frosts and hoarfrosts (September) and the latest spring frosts and hoarfrosts (April-May), by two to four, even five weeks earlier, respectively later, by considering the average dates characteristic of each level of relief in the Apuseni Mountains.

Thus, for the peripheral areas of the mountains (see chart 1), *the earliest frosts* occur in the second half of September (14.09 at Huedin, 17.09 at Ştei and 28.09 at Borod), with the exception of Gurahonț meteo station, where under the local physical geographic conditions, the earliest frost occured on 1.09. *The latest frosts* occured in the second half of May (Huedin, Borod, Gurahonț) and even in the first part of June (2.06 at Ştei). The higher the altitude is, these phenomena occur earlier and earlier, respectively later and later, being present almost all year round at Stâna de Vale and Vlădeasa 1800 because the extreme date of the first frost occurs at the beginning of August (3.08 at Vlădeasa 1800 and 7.08 at Stâna de Vale), and that of the latest frost, at the end of July (20.07 at Stâna de Vale and 25.07 at Vlădeasa 1800).

The earliest autumn frosts and the latest spring frosts are the most dangerous ones usually because they are accompanied by hoarfrosts (chart 2), which might damage the crops at the foot of the Apuseni Mountains before the end or the beginning of the vegetational cycle. These frosts affect negatively the high area of the mountains if they occur at the beginning, the end or even in peak summer and take by surprise the cattle went to grass or the tourists lightly dressed.

5. Conclusions

Frost and hoarfrost are meteorological phenomena common to the climate of the Apuseni Mountains. The frost phenomenon does not necessarily occur simultaneously in air, at ground level and in the ground. Thus, the lightest frosts are visible only at ground level and enter it approximately 1-2 cm, whereas the most intense ones affect simultaneously the ground and the air and can enter the ground of the intramountainous depressions with a thickness of over 100 cm. *Hoarfrost* can occur at nighttime or in the morning before sunrise on cool and calm weather, in the spring, autumn or winter, by sublimation of the water vapours from air onto the objects whose temperature falls below 0^0C as a result of nocturnal radiative cooling.

Frost and hoarfrost can become dangerous to the economy of the Apuseni Mountains if:

- they occur off-season by 2-3 weeks earlier in autumn, or later in the spring comparatively with the average dates;
- the area is exposed to direct advection of cold air;
- the advected air is extremely cold;
- the cooling is mixed (advective-radiative);
- the frost occurs simultaneously on the ground and in the air;
- the frost is accompanied by hoarfrost or other winter meteorological phenomena (sleet, snow etc.);
- they cover an extended area;
- there are favourable local conditions;
- they are very intense;
- the duration of the frost exceeds 8-10 hours sequentially.

Under these circumstances, in the Apuseni Mountains, the frost and hoarfrost can sometimes extremely damage the crops at the foot of the mountain, but can be less damaging in comparison with other really catastrophic natural phenomena.

BIBLIOGRAPHY

Bacinschi, D.(1957), *Răcirile şi brumele din septembrie 1956*, Meteorologia şi hidrologia, Martie, *1*, Bucureşti: 72-79.

Bâzâc, Gh. (1983), *Influenţa reliefului asupra principalelor caracteristici ale climei României,* Edit. Acad. R.S.R., Bucureşti: 179.

Bălescu, O., I., Iliescu, Viorica (1963), *Studiul condiţiilor meteo-sinoptice ale intervalelor caracteristice care favorizează îngheţul şi dezgheţul principalelor râuri din R.P.R.,* Cul. lucr./1961, C.S.A., I.M., Bucureşti: 69-97.

Berindei, O., I., Măhăra, Gh., Pop, I., Posea, Aurora (1977), *Câmpia Crişurilor, Crişul Repede, Ţara Beiuşului,* Edit. Şt. şi Enciclop., Bucureşti: 366.

Berindei, O.,I., Pop, I., Gr. (1972), *Judeţul Bihor,* Edit. Acad. R.S.R., Bucureşti: 159.Bogdan, Octavia (1978), *Fenomene climatice de iarnă şi de vară*, Edit. Şt. şi Enciclop., Bucureşti: 120.

Bogdan, Octavia, Dragotă, Carmen (2000), *Risks of frost occurrence in Romania,* Proc. Rom., Acad., B, II, Bucureşti: 147-153.

Bogdan, Octavia, Iliescu, Maria (1971), *Condiţiile climatice din masivele Bihor-Vlădeasa şi Gilău în sprijinul desfăşurării activităţilor turistice,* Lucr. celui de al II-lea Colocv. Naţ. de Geogr. Tur., Inst. de Geogr., Bucureşti: 119-129.

Bogdan, Octavia, Niculescu, Elena (1992), *Phénomènes climatiques extrêmes pendant le dernier siècle en Roumanie,* R.R.Géogr., 36, Bucureşti: 57-62.

Bogdan, Octavia, Niculescu, Elena (1999), *Riscurile climatice din România,* Sega International, Bucureşti: 280.

Bujorean, G. (1936), *Date climatologice comparative între Stâna de Vale (1100 m alt.) şi Cluj (408 m alt.),* Bul. Grăd. Bot. şi a Muz. Bot. de la Univ. din Cluj, XVI, *1-4,* Cluj: 42-54.

Ciulache, S., Ionac, Nicoleta (1995), *Fenomene atmosferice de risc şi catastrofe climatice,* Edit. Şt., Bucureşti: 179.

Dissescu, C.A. (1929), *Studiu asupra primei şi ultimei zile de îngheţ din ţinuturile alpine,* Bul. Meteor. lunar, Octombrie, I.M.C., Bucureşti.

Dragotă, Carmen (1994), *Particularităţi în distribuţia pe teritoriul României a îngheţului în aer,* A.U.O., IV, Oradea: 76-82.

Gaceu, O. (2005), *Clima şi riscurile climatice din Munţii Bihor şi Vlădeasa*, Edit. Univ. din Oradea, Oradea: 284 p.

Gaceu, O. (2009), *Elemente de climatologie practică,* Editura Universităţii din Oradea, ed. a II-a, Oradea: 148 p.

Iliescu, Maria (1973), *Consideraţii asupra frecvenţei şi repartiţiei unor fenomene atmosferice din bazinul românesc al Crişului Repede,* Hidrotehnica, 18, *10*, Bucureşti: 549-554.

Iliescu, Maria, Bogdan, Octavia (1973), *Scurtă caracterizare climatică a perioadei reci a anului în masivele Bihor-Vlădeasa şi Muntele Mare-Gilău*, B.S.S.G.R., III (LXXIII), Bucureşti:162-172.

Mac, I., Sorocovschi, V. (1987), *Le rolle du relief dans la distribution de certains éléments climatique au nord-ouest de la Roumanie*, SUBB, Geol-Geogr., XXXII, 3, Cluj-Napoca: 3-9.

Măhăra, Gh. (1992), *Fenomenul de îngheţ şi brumă pe teritoriul României,* Terra, XXIV (XLIV), *3-4*, Bucureşti: 81-85.

Morariu, T., Bogdan, Octavia, Maier, A. (1980), *Judeţul Alba,* Edit. Acad., Bucureşti: 180.

Stoenescu, Şt. M. (1950), *Influenţa îngheţului asupra transporturilor,* Rev. Transp. şi comunic., I, *3*, Bucureşti.

Topor, N. (1958), *Bruma şi îngheţul. Prevederea şi prevenirea lor,* Edit. Agrosilvică, Bucureşti: 140.

Ţâştea, D. (1989), *Indicele de persistenţă a îngheţului,* Studii şi Cercet., 3, Meteor., I.N.M.H., Bucureşti: 115-119.

*** (1983), *Geografia României, I, Geografia fizică,* Edit. Acad. R.S.R, Bucureşti.