FREEZING RAIN PHENOMENA. CASE STUDY: BUCHAREST METROPOLITAN AREA, 24-29 JANUARY 2019

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Abstract. ***Freezing rain phenomena. Case study: Bucharest metropolitan area, January 24-29, 2019.*** The paper has a structure with four parts and presents the climatic risk aspects that happened in Romania during the winter of the year 2019, concentrating on Bucharest, where a very rare and dangerous phenomenon occurred, `freezing rain`. The first part contains the theoretical analysis of the subject under discussion (the notion of risk and freezing rain), in the second part we analyzed the synoptic context (the causes that led to the phenomena) and the datacollected, the third part presents the results of the research (the duration of phenomena and the case study in the city), and the last part deals with proposed measures in order to reduce the risk of freezing rain, measures that can apply to any dangerous weather phenomena with freezing deposits. Therefore, the study aims to analyze this risk starting from the theoretical explanation of the synoptic context that generated its production to the quantitative analysis of the phenomena. To achieve this objective, the periods ECMWF models and the synoptic databases were accessed, with the help of which the representation and evolution of the phenomena was managed.

Keywords: freezing rain, climatic risk, weather phenomena, Bucharest metropolitan area.

1. INTRODUCTION

1.1. Understanding the risk notion

The risk represents the expected level of losses in case of potential catastrophic event occurrence. The notion has two dimensions: objective and subjective. The first dimension comes from the evaluation of probable damages, while the other one is the result of a perception process.

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The risk is tightly connected with the presence of human being in the area, capable of understanding the causes and the effects of the phenomena. Without a human presence, we can't talk about risks, only hazard, the risk occurring only when we deal with people. The risk depends on the hazard and the vulnerability of the exposed society. The risk elements are represented by people, buildings, infrastructure, services, and so on. The fact that the risk implies also the human society assumes taking measures to overcome the danger. As a consequence, the anthropic factor has a double role in relation to risk – as a risk factor, but also as a reducing risk factor.

The risk represents a function between hazard, vulnerability, exposure, and resilience, which is defined by the formula $\boldsymbol{R} = \boldsymbol{H} \cdot \boldsymbol{V}$. In short terms, the risk is the product of hazard and vulnerability (Armaș, 2008).

Of all the risk categories as an environmental component, weather climatic risks, and hazard presents a specific character due to their form and fast development. Climatic risk frequency had grown a lot in the last ten years of the twentieth century, the mentioned period being known as the International Decade of Reducing Effects of Natural Disaster. During this period, according to World Meteorological Organization (WMO) presented on 23.06.2006, International Meteorological Day, around 65% of the damage and around 90% of the human loss were caused by catastrophes due to weather or climate. Unfortunately, most of the damage occurred in developing countries. Due to this, monitoring climatic risk is necessary to prevent and reduce the negative consequences if not to avoid them (Sofroni et. al, 2009).

From the start it is important to say that not all climatic phenomena can generate risk and neither all climatic risk phenomena can present the same intensity, the potentially catastrophic consequences of this risk are gradual according to hazard. Due to this, in the field of climatology and weather using the terms risk and hazard represents a new meaning according to their variation (Sofroni et. al, 2009).

Because of weather climatic hazards, other risks can occur, generating other geomorphic, hydrological, ecological or pedological hazards, creating a whole chain of them (Bogdan, 2004, 2007). The main consequence of them represents the economic risk that can take various forms, for example, the destruction of national roads and railroads, along with compromised crops, these things being the beginning of social risk that led to reducing the quality of life and living standards (Sofroni et. al, 2009).

1.2. Understanding Freezing rain phenomena

Freezing rain represents a weather phenomenon that appears when rain meets a very cold surface and freezes instantly. It is a very rare phenomenon that is characterized by the over-cooled raindrops that freeze instantly when touching the earth or objects that have negative temperatures on the ground. The raindrops become over-cooled while going through an air layer under freezing temperature hundreds of meters above the earth's surface and then freezes when meeting any surface, including earth, trees, electrical wires, airships, and cars. The resulting ice, called veneer, can have a thickness of a few centimeters, and cover all exposed surfaces. This phenomenon is encountered mostly in Europe in wintertime (December to February) and presents a high risk for human activities, air and land transportation, infrastructure, and distribution of electrical power (Bălescu, 1962). Among the main risk aspects ar: the heavyweight of the deposition, the long life of the deposition, the negative temperatures that are preserved and that acts on the vegetation causing the cellular juices freezing and destroying vegetal tissues, the reduced diameter of deposition when it has high density and remains a long time on the conductors, along with high wind speed and complex deposition that have higher density and weight as a consequence of mechanical settlement of the higher layers and wind pressure (Grecu, 2009).

Fig. 1. Freezing rain in Bucharest (Bărbărie, 26.01.2019)

2. MATERIALS AND METHODS

2.1. Theoretical considerations – the general synoptic context

During the 24th to 26thof January, 2019, Central and East Europe was under the influence of an anticyclonic regime that led the advection of a cold air mass over these parts of Europe,freezing rain phenomena was associated with a Mediterranean anticyclone of low pressure that formed over the Genova Golf on the 23th of January, 2019 (ECMWF, 2019).The next two days the cyclonic formation moved initially to South-East Europe and then it changed its course to East, near to the Greek border creating unstable and harsh weather conditions over the Balkan Peninsula. This, generated freezing rain in South-East and South of Romania, including in Bucharest. Dueto this phenomenon, the highways and national roads from the South and East part of the country were closed beginning with the evening of the 24thof January, and on the 25th of January a lot of flights got cancelled. The heavy ice deposition on the electrical wires led to power outages, while the emergency services reported around 100 persons in the first evening having sprains or fractures due to fallingon ice.

The first ECMWF model that caught the horizontal structure of the phenomena that affected Bucharest appeared on the 21st of January 00 UTC and presented a falling probability of freezing rain higher than 5mm/24h, while during the period 24.01.2019 06 UTC and 25.01.2019 06 UTC the model presented a probability of 30%. This model showed it was capable of capturing this dangerous weather phenomenon three days before it happened (fig. 2) (ECMWF, 2019), (Andrei et. al., 2019).

According to ECMWF models from the 24thto 25th January 2019, South-East Europe, including our country, was crossed by acold atmospheric front with a rate of 1mm/h for a few hours, which led to creating a thick layer of ice on the ground.

The eventisbest described by the temperature profile caught by an atmospheric soundingat 00 UTC hour on the 25th of January 2019 in Bucharest-Afumați weather station, which showed a warm atmospheric layer between 910 hPa and 860 hPa, here the temperature is above zero (yellow zone), while the temperature at 2m height showed -0.5°C (Fig. 3) (ECMWF, 2019).

Also locally, the National Meteorological Administration released an orange warning of bad weather for many zones from South and South-East counties, Ialomița, Argeș, Prahova, Giurgiu, Dâmbovița, Teleorman, Călărași and Ilfov county, including the city of Bucharest, where rainfalls with significant depositions of veneer would have occurred (ANM, 2019)(Fig. 4).

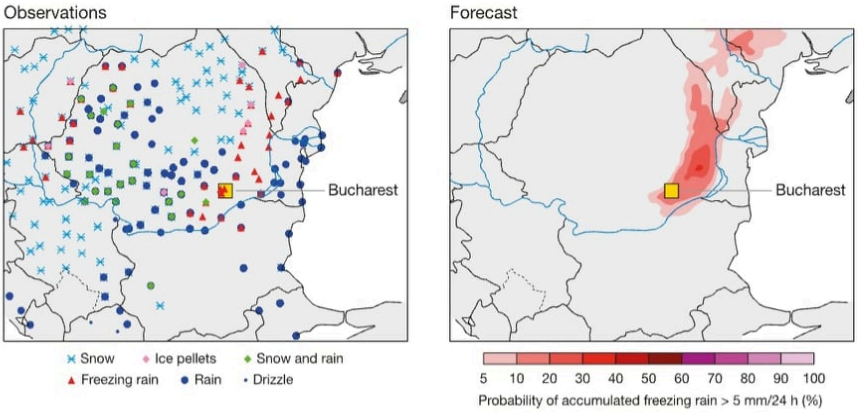

Fig. 2. ECMWF model for rainfall during 24th of January 06UTC hour – 25th of January 06 UTC hour (left) and the probability of more than 5mm freezing rain from the 21st of January 00 UTC hour (right) (Source: ECMWF, 2019)

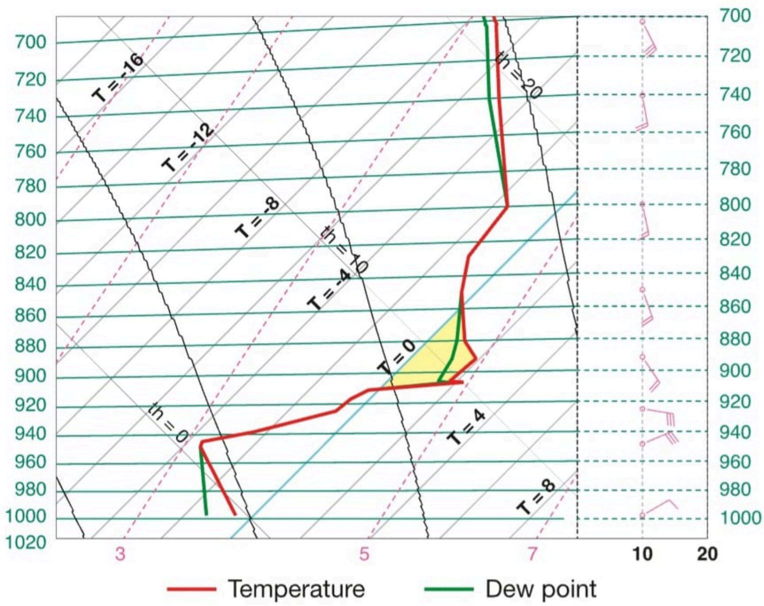

Fig. 3. The temperature profilefrom Bucharest-Afumați weather station on the 25th of January 2019 00UTC hour (Source: ECMWF, 2019)

Fig. 4. National map of veneer depositions on the 24th of January 2019, 06 UTC hour (Source:ANM, 2019)

2.2. Data collecting

In order to process the case study, we have accessed SYNOP observations from the global archives of the World Meteorological Organization (WMO), from where data for the Bucharest-Băneasa Weather Station were extracted. When we want to analyze freezing rain phenomena there are a lot of issues to be considered. For example, some weather stations reported the phenomena for limited periods of time or not at all during the night, this happened according to the observation schedule of the station personnel. In order to avoid these problems, the present study used themethodology from the studies of (Cortinas, et.al., 2004) and (McCray,et.al., 2009) where, in order to analyze freezing rain in the USA, research was based only on weather stations that reported hourly weather condition and evolution of the phenomena.In the Bucharest area, there are three weather stations, Bucharest- Băneasa, Bucharest-Filaret, and Bucharest-Afumați, from which by applying the criteria mentioned above, only Bucharest- Băneasa station is included in the analysis. At this station, synoptic reports were available hourly (these reportsincluded coding of the phenomena, according to the present international weather code: 66 for freezing rain and 67 for moderate or strong freezing rain) and every three hours the stage of the phenomena was also reported (deposition, preserving, and regression) in the synoptic message.

Table 1. Air temperature variation at Bucharest-Băneasa station during 24-29.01.20219, (Source: Weather Graphics. Global Surface Archives)

Date	UTC hour	Temperature (°C)
24.01.2019	03	-0,8
	06	-0,8
	09	-0,5
	12	-0,3
	15	-0,9
	18	-1
25.01.2019	03	-0,5
	06	-1
	09	-2
	12	-2,4
	15	-2,1
	18	-1,8
26.01.2019	06	-0,7
	09	-0,3
	12	-0,3
	15	-0,3
	18	-0,4
27.01.2019	09	-0,3
	12	-1,8
	15	0,4
	18	-2,2
28.01.2019	09	-2,9
	12	-3,8
	15	1,8
	18	-1,3
29.01.2019	09	-4
	12	-2,6
	15	4,1
	18	5,4

3. RESULTS AND DISCUSSIONS

The analyzed freezing rain case started in Bucharest on the 24th of January 2019, at 02:56 UTC hour at a temperature of -0,8°C, being present on the ground and contending objects, the initial layer of ice being 3cm thick. During this case, the lowest temperature was -4°Con the 29th of January 2019, 06 UTC hour, and the highest one of 5,4°C, on the same day 18 UTC hour (ANM, 2019).

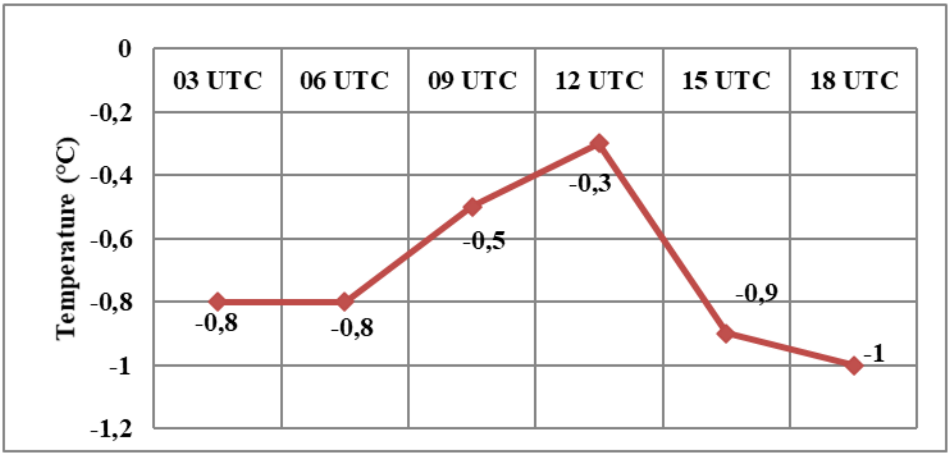

Fig. 5 Air temperature variation at Bucharest-Băneasa Weather Station on the 24th of January 2019

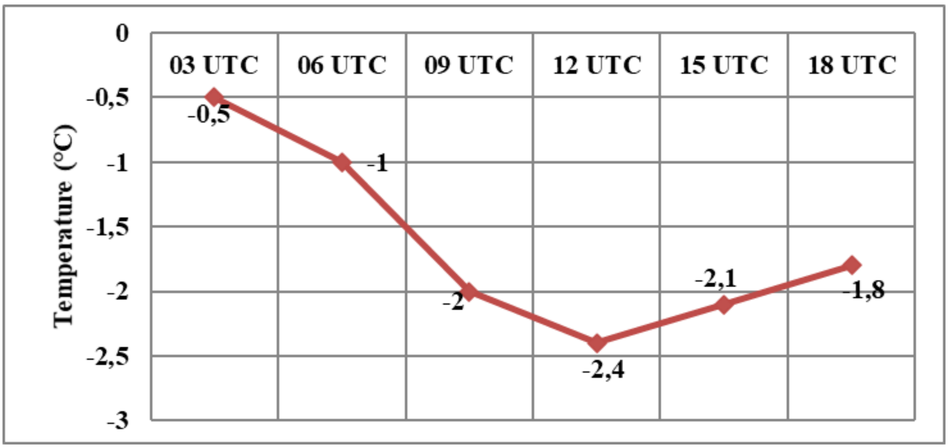

Fig. 6 Air temperature variation at Bucharest-Băneasa Weather Station on the 25th of January 2019

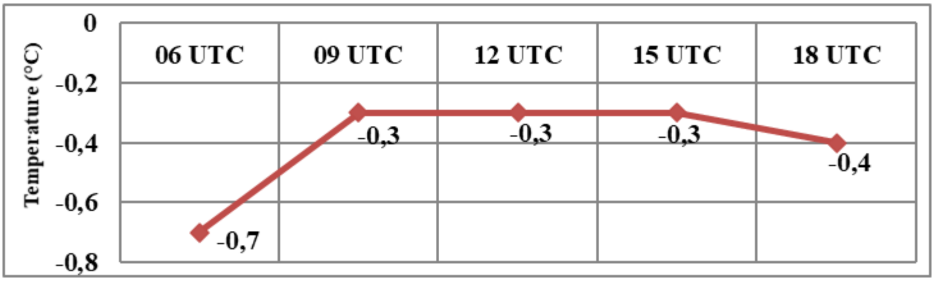

Fig. 7 Air temperature variation for Bucharest-Băneasa Weather Station on the 26th of January 2019

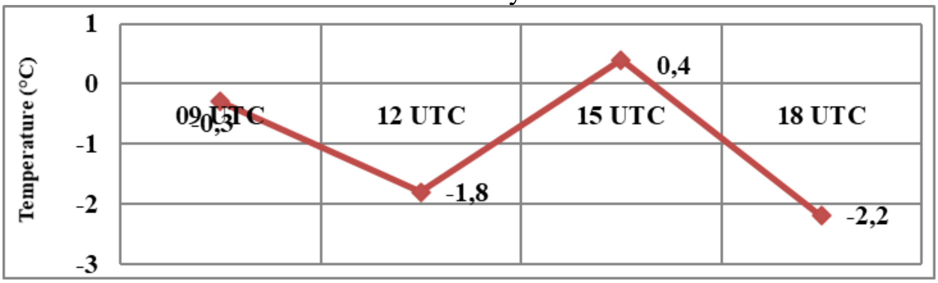

Fig. 8 Air temperature variation for Bucharest-Băneasa Weather Station on the 27thof January 2019

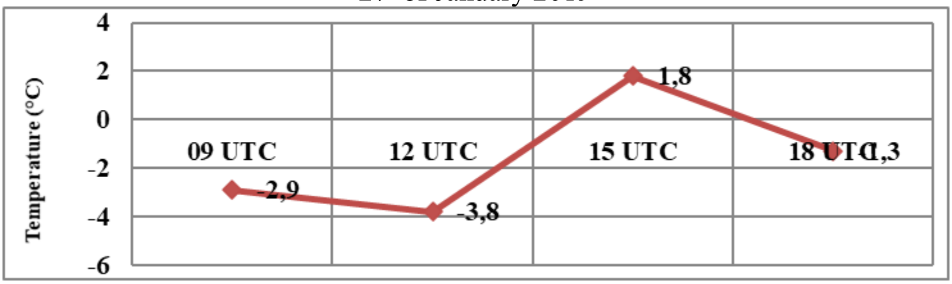

Fig. 9 Air temperature variation for Bucharest-Băneasa Weather Station on the 28th of January 2019

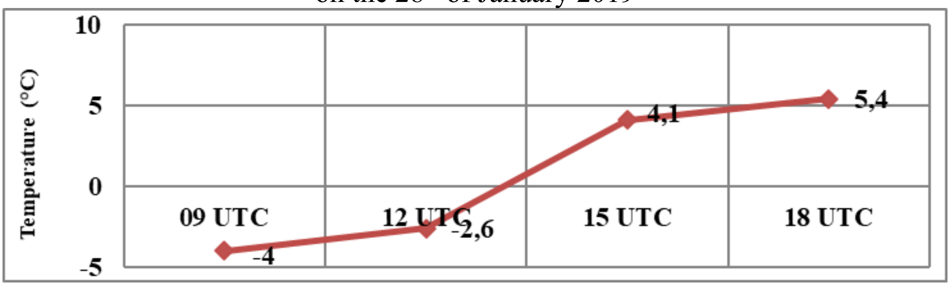

Fig. 10 Air temperature variation for Bucharest-Băneasa Weather Station on the 29th of January 2019

According to graphic representations from figures 5-10 we can say that the phenomena started on the 24th of January, approximately at 03 UTC at a temperature of -0,8°C, on the first day reaching -1°C. On the 25th, the minimum temperature reached -2,4°C, causing the deposition of an important quantity of ice, on the 26th, the temperatures were mostly constant at a value of -0,3 - -0,4°C, with a minimum value of -0,7°Cat 06 UTC. On the 27th, the maximum temperature reached 0,4°Cat 15 UTC and the minimum value was -2,2 at 18 UTC. On the 28th of January, the highest temperature of the entire period was recorded, the maximum value reaching 1,8°Cat 15 UTC, and during the last day, the temperature had a constant rise starting from the minimum value of -4°Cat 09 UTC till the value of 5,4°Cat 18 UTC, when mostly of the deposition in Bucharest started melting.

Fig. 11. Freezing rain in Bucharest (Albu, 27.01.2019)

Fig. 12. Damages recorded in the Bucharest area (Albu, 28.01.2019)

After five days in which the phenomena persisted on the ground and on contending objects, on the sixth day, on the 29th of January 2019, the rain stopped, the phenomena entered the maintaining phase andit was also the end of the deposition. After these six days, there were another five days of recovering in which the most part of the ice melted. The duration of the increase was 1944 minutes, and the effective duration of the studied case was 7744 minutes (ANM, 2019). During this time, National Meteorological Administration (ANM) cast out 47 now-casting warnings for all the cities in the South-East of Romania. Due to these warnings many roads and highways that connect Bucharest with the rest of the country were closed, and the Henry Coandă airport was closed for three hours on the 25th of January, causing theperturbation of the air traffic.

Just in Bucharest, due to the important quantity of ice depositions a number of 2622 trees and branches fell, destroying totally or partially 759 cars, the public transportation also shut down because of repeated power outages. According to the Romanian Urgency services, during the period of 24-26.01.2019, there were received 154 calls for medical emergencies and 4 road collisions (Andrei, et.al., 2019).

Fig. 13. Damages recorded in Bucharest area (Albu, 28.01.2019)

4. FREEZING RAINRISK REDUCTION MEASURES

Atmospheric risk phenomena are characterized by catastrophic impacts on the population both in the short and medium term by producing victims and property damage, and in the long term by degrading land that reduces their productive potential (Sofroni et. al, 2009). Risk reduction measures fall into two categories: structural measures and non-structural measures.

4.1. Structural measures

Structural measures are the most effective solutions to atmospheric risk problems. These are technical measures to protect the population and materials against these risks that reduce the danger and probability of occurrence of the event (Bărbărie, 2017).

Examples of structural measures include the design of overhead power lines for maximum loads (maximum wind, maximum deposits) based on meteorological observation data on ice deposits and wind characteristics, the choice of overhead power lines, so as to avoid icy regions and strong winds, exploiting the advantages offered by the land, respectively avoiding slopes and coasts perpendicular to the direction of humid air masses, preventive heating of conductors by ensuring a circulation of power that prevents their cooling below 0 °C, measures for melting ice formed on line conductors and the installation of frost warnings designed to alarm both the exceeding of the allowable weight of the ice-covered conductor and the inadmissible increase of the load due to frost deposits and wind intensifications (Grecu, 2009).

4.2. Non-structural measures

Non-structural measures are a number of ways of prevention and protection with minimal impact on the environment. They are very effective in the long run in forecasting atmospheric risks (Bărbărie, 2017).

An example of a non-structural measure that can be applied for this study is represented by the elaboration of atmospheric risk maps. They fall into two categories: general maps (for all atmospheric risk phenomena) and special maps (for a certain risk phenomenon, in this case, the freezing rain phenomenon).

Most risk maps show more the territorial distribution of the vulnerability and less the quality of the risk-based on quantitative analysis. The indirect impact on the population is manifested mentally, the training and education of the population having a primary role in reducing the effects. The population's reaction to the atmospheric risk phenomena is manifested by: passive acceptance, preventive and defensive actions elaborated on the evaluation of meteorological data, as well as the modification and direct control of the weather and climate. In order to reduce the effects of the atmospheric risk phenomena are necessary: knowledge of weather forecasts, monitoring of atmospheric risk factors and assessment of material costs to reduce damage (Sofroni et. Al, 2009).

5. CONCLUSIONS

This paper analyzed the atmospheric risk phenomenon called Freezing rain or "frozen rain" with emphasis on the event in Bucharest from January 24-29, 2019. The analyzed case study held for 6 days, more precisely on a total duration of the event of 7744 minutes, the interval in which at the meteorological station Bucharest-Băneasa has registered a minimum temperature of -4 °C and a maximum temperature of 5.4 °C, both values being recorded on the last day of analysis, followed by another 5 days of post-event return.

The main damages that affected the Bucharest area as a result of this extreme meteorological phenomenon were the fall of 2,622 trees and branches, the total or partial damage of 759 cars and 154 rescue calls for 4 car accidents and various ruptures and fractures of people due to falling on the ice.

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