HAIL IN THE AREA COVERED DISTRIBUTION OF WSR-98D RADAR FROM BOBOHALMA

N. MAIER[1]*, DENISA LACATUS*[1]*, TATIANA RUS*[1]

ABSTRACT.– Hail in the area covered distribution of WSR-98D radar from **Bobohalma.** Using radar data to make a „climatology” of hail was imposed because of the fine resolution of the radar, both spatial and temporal. The data used in the “climatology” are taken from 6 seasons of summer, June–July–August, between the years 2004–2009. Based on parameters provided by the WSR-98D radar at Bobohalma maps of areas in which the storm cores appear depending on the diameter and the severity of hail were prepared. It was noted that the areas where the frequency of the nuclei of the hailstorm is high does not overlap with the areas with exceeding probability of 70% of severe hail of large diameter contained the nuclei to reach the ground.

Keywords: hail, relief, centers of storm

1. INTRODUCTION

Theories about the formation of hail in convective clouds are complex and incomplete, which is why the forecast and detection of the phenomena are difficult tasks to perform under the operating system. Furthermore, real-time response data are not precise and checks are difficult to make. Areas where local climatic data and studies related to hail exist, are often subject to interest for damages that occur on certain goods (agriculture). Current maps, which represent the distribution of hail in Romania (Romania Climate 2008), are made with the aid of data from meteorological stations. The weather station network is quite thin in order to cover the entire territory. In addition it should be noted that the area where hail falls is a small portion compared to the size of the active area of the storm. To cover this shortfall statistical maps have been made, with the aid of the weather radar, showing an overview of areas where there is a high probability of hail, especially large diameter hail.

The use of radar data has clearly become the compulsory element of any technique used to estimate the existence or absence of hail in convective clouds.

Data were used from the S-band Doppler radar of type WSR-98D, installed at Bobohalma near Târnăveni. Fine spatial and temporal resolution allows a detailed statistical analysis of the development of convective clouds (Maier 2009).

In the influence zone of the Bobohalma radar, the areas that are most affected by hail are the ones influenced by synoptic disturbances, mesoscale modulated by topography and diurnal heating.

Forecast of the occurrence of hail, estimation of severity and location, are complex issues for each area (Brimelow 2004). The purpose of this paper is to identify those areas where the incidence and severity of the hail is high, and also to investigate the feasibility of producing maps of the large hail diameter (> 4 cm).

2. DATA AND METHODS

The data used were received from the S-band Doppler radar of type WSR-98D, installed Bobohalma (RDBB). The RDBB coverage area is 166106 km^2. Product 38 of composite reflectivity, provided by the radar at Bobohalma (RDBB) for 6 seasons of summer, June–July–August between the years 2004–2009, was used. This product is available from 6 to 6 minutes and contains information relating to the nuclei of the storm. Nuclei are defined by their radius and azimuth.

For positioning the nuclei of the storms in a Cartesian coordinate system and then on a geographical map, the radius and azimuth were turned in x and y coordinates, in other words from inverse polar coordinates to Cartesian coordinates. The automatic conversion of polar coordinates in Cartesian coordinates was done with great difficulty, as geographical degrees converge clockwise in the system and in the Cartesian system the degrees converge trigonometrically. Geographical degrees have a starting point on the OY axis, while the geometric degrees' starting point is on the OX axis. 181238 files have been processed and 731000 contained nuclei, from which 173797 had nuclei containing hail and 12834 of them had probability (normal and severe) over 70% that the hail contained in them will reach the ground. Thus, at the end of the processing, each detected core of the storm has a corresponding point on a graph with Cartesian coordinates, that has that has the unit as „km" on both of the axes OX and OY. This system of coordinates was divided into squares with side of 10 km and the cores found in these areas were numbered. Using these absolute frequencies, radar maps centered at the point were made. These absolute frequency maps were applied on an administrative map of Romania, with the same scale as the processed map.

Maps with key step of 10 km were made, meaning that 1661 pixels size of 100 km^2 were obtained. The coverage of these pixels is 166100 km^2. The key step of 10 km was chosen to highlight the geographical relief groups. Maps of absolute frequency of the areas in which most nuclei containing hail storms of different sizes and with different probabilities of reaching the ground appear were obtained. Then, two filters of these nuclei were done. During the first screening only those situations for which the probability of severe hail was over 70% and the probability of PG was indifferent were taken, and for the second screening only the nuclei with both storm probabilities (normal and severe) over 70% were analyzed. Only the maps with relative frequency were analyzed, thus the areas obtained were those where few cases where nuclei containing hail storm are detected, but there is high probability that hail contained in the storm reaches the ground; and are areas with high frequency of nuclei with hail, but with low probability that hail will fall in that area. The analysis of the core areas within which large hail occurs was done for the situation when the diameter of the hail was greater than 4 cm.

3. RESULTS

During the period of analysis of the phenomena of hail formation, based on the information provided by the weather radar WSR-98D from Bobohalma, some useful results for the operational activity of forecasting of immediate meteorological phenomena, especially hail, are highlighted.

The weather radar revealed the outline of three areas where cloudy formations that could provide conditions for forming hail were present.

The first area corresponds to the zone with more than 180 cases (disposed concentrically in spreads from 20 to 20 cases). These areas correspond to the units of the Apuseni Mountains, with maximum extension in the counties of Cluj and Alba and a peak in Bihor county (area of Stâna de Vale, the western slopes of Vlădeasa and Bihor Mountains); of Meridional Mountains, especially in Parang and Fagaras Mountains; of the volcanic mountains of the Oriental Group, especially the Gurghiului, Harghita and Călimani Bârgăului Mountains; and two smaller areas with values of 180–220 cases that outline the Gutâi-Țibleș-Rodna Mountains and the submontane area, especially the Lapus Depression, and that of the Perşani Mountains. (Figure 1).

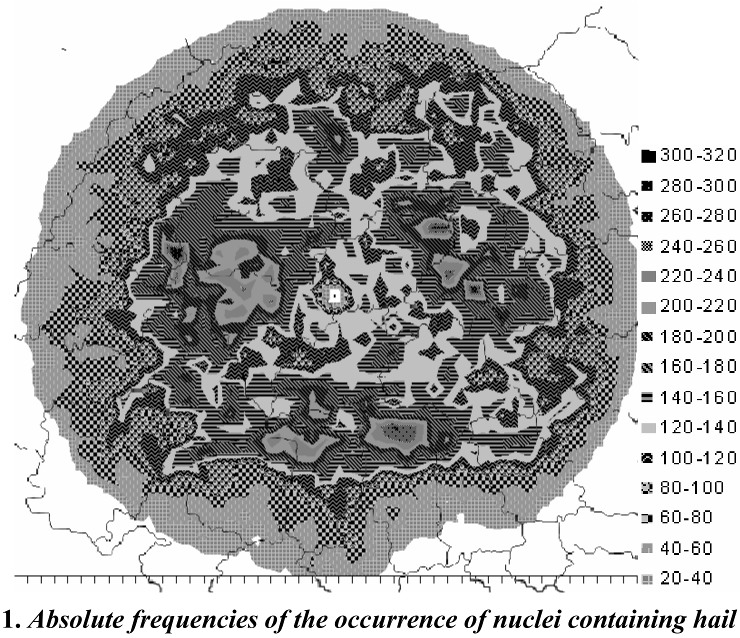


Fig. 1. ***Absolute frequencies of the occurrence of nuclei containing hail storm***

The second area corresponds to areas with values between 120–180 cases. Transylvania Plateau has values between 120–160 cases especially in the central region, and values between 140–180 cases in the peripheral area of depressions and marginal corridors. In this area, a sector corresponding to the Secaş and Tarnavelor Hills and the Alba Iulia–Turda corridor, with minimum values of 80–120 cases, was highlighted. With the same values of 80–120 cases, a small area in the northeast of Salaj county, overlapping the Somes Plateau (Şimişna-Gârbău Hills) is highlighted, along with another lane (Valley of Sălăuța) which separates the Țibles Mountains and the Rodna Mountains, (figure 1).

Areas with values below 80 cases, (figure 1), correspond to areas outside the Carpathians Mountains, and are at a greater distance than 150 km from the radar, thus the cloudy formations are partly shielded by the Carpathian Arch and others are under the angle of the camera and only their peaks can be detected. An area with low values is that near the radar, as cloudy formations are over the angle of the camera.

If at the first analysis, the areas with high levels are quite small, and occur mainly in the high mountain area, after the first filtering, nuclei containing hail storms are detected in the zones adjacent to the mountains (corridors, submontane hills and depressions) which would correspond to the maturation and movement of the storm core from the formation areas, from the mountain areas to low areas (depressions, valleys, plateaus). Thus, if the existence of large cells of hail on the mountain ridges would correspond to the beginning of a convection, the display of the areas after the second screening would correspond to the maturation and movement of the core of the hailstorm, under the influence of the currents of the dominant circulation, or of the lower mountain breezes, (figure 2). The screening was performed/done depending on the PG indicators (probability of hail) and PGS indicators (probability of severe hail), when their values are above 70%.

Thus, it can easily be observed that the considered data is contained in an interval starting from 5 cases and going up to 40 cases, grouped in 7 classes of intensity, which outline several areas in the territory. In order to highlight the mountain areas with a small number of cases, below 5, for the class of values ranging between 0 and 5 cases, the white color was chosen.

The most extensive areas with high frequencies of 15 cases, are grouped in the counties of Salaj, Cluj, Mures, Alba and Hunedoara. Outside these areas with values of 10–15 cases are: the hilly region of Satu Mare, Mures, Bistrita Nasaud and Maramures, including the Maramures and Lapus Depression. Areas with more than 20 cases in these districts overlap: the Almas-Agrij Depression in the county of Salaj, eastern slopes of The Great Mount (Muntele Mare) in the Cluj county, the Hills of Cluj and Dej, and the Feleacul Hills that has over 35 cases, the Iara and Hăşdate depressions, the Transylvania Plain (which is extended in the counties of Mures and Bistrita Nasaud); the Alba County area that overlaps the Mountains of Trascău, extending in Hunedoara County, over the Metaliferi Mountains and the Mures Corridor. The way in which these areas are arranged, in the NW-SE direction, over the Silvaniei and Meseş Hills indicates the direction of penetration of the masses of moist oceanic air, and the meeting with the Mediterranean masses of hot and humid air that come from SW part of the Mures Corridor, curving over the Metaliferi Mountains.

Wider areas with values greater than 15 cases occur on southern slopes of the Meridionali Mountains, with extensions in the Tarnavelor Plateau and the

Subcarpathians of Oltenia, south-eastern slopes of the Carpathians of the Curve and the eastern slopes of the Orientali Mountains (figure 2).

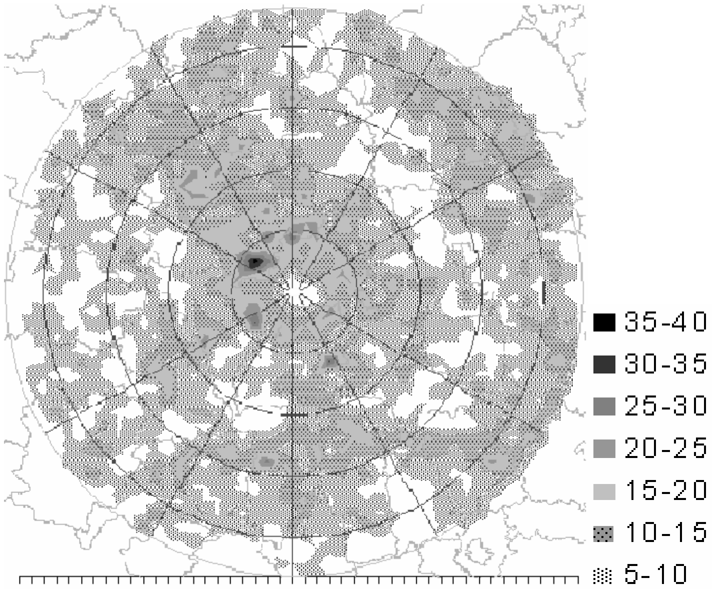


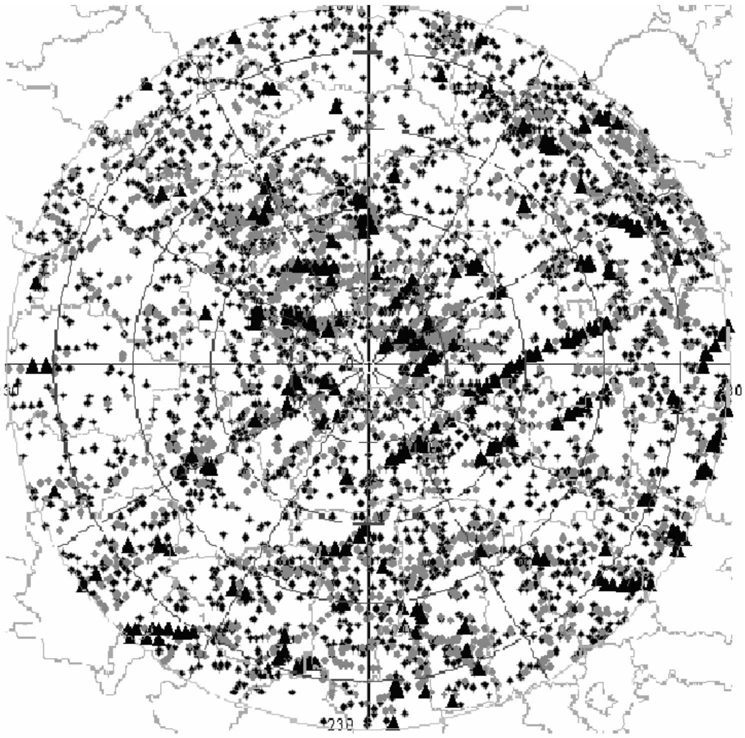
Fig. 2. ***Absolute frequencies of the occurrence of nuclei containing hailstorms with PG and PGS> 70%***

The vulnerability of a territory to hail is conditioned by both the frequency of the phenomena and especially by the size of the hail. The analysis of the phenomena, during the considered period, highlights some spatial features. (figure 3).

In the Western region (the Western Plain and Hills, the western slope of the Occidental Carpathians) are most of the cases with diameter under 5 cm, except few small areas that belong the Poiana Rusca Mountains – Hațeg Depression, Timis – Cerna Corridor and the area adjacent to it, and the Silvaniei Hills.

The central-eastern sector of the Apuseni Mountains and Transylvanian Depression has a wide variety of cases related to the diameter of the hail, with areas in which hail with diameter size over 7 cm was detected, (figure 3). These are related to the position of valley corridors and relief units in relation to the movement of air masses or of the mountain breeze. Such areas are: the western sector of Salaj county (the Almas-Agrij depression), the hilly Feleacul Massif – Somes Mic Corridor – Unguraş and Sicul Hills, the Turda-Aries Corridor, the Somes Mare Corridor, the Fagaras Depression and the Madarasi Hills.

The eastern mountain sector (the Oriental Carpathians) and the southern mountain sector (the Occidental Carpathians) including the submontane hilly areas, highlight the appearance of areas in which in the hail storm nuclei hail with diameter exceeding 7 cm was detected. These areas are usually inside areas of inflection – air masses management corridors or areas of morphologically mountain-lowland or Carpathian under hills-plains contact. For example: Vatra Dornei – Mestecãnis – Moldovian Corridor, Odorhei – Vlahița – Miercurea Ciuc, Subcarpathians of Vrancea – Siret Plain, Subcarpathians of Prahova, Brasov – Tg. Secuiesc – Oituz, Getici Subcarpathians – Getic Plateau.



+diameter between 4 cm and 5 cm; ●diameter between 5 cm and 7 cm; ▲diameter > 7 cm

Fig. 3. ***Areas of developing storm core containing large diameter hail***

The overlap of the areas with hail of diameter greater than 4 cm over the area where nuclei of hailstorm with severe and normal probability over 70% are detected, can be easily observed (figure 2 and figure 3). Hence the conclusion that in these areas with high absolute frequency, outlined above, the probability of appearance of medium and large hail increases.

The number of cases of storm cores containing different sizes of hail detected by the radar are presented in Table 1. Thus the first column represents the diameter of the hail, the second column contains the number of nuclei detected by the radar after the second screening, and the third column contains the total number of nuclei of different diameters detected in the 6 years that were analyzed and the last column represents the probability that the nuclei containing hail of different sizes can be found among the nuclei of the storms with PG and PGS> 70%.

Table 1. ***Number of cases of nuclei with different diameters hail***

Diameter of hail (cm)	Number of cases PG și PSG > 70%	Number of cases	Probability %
>10,16	40	40	100
9,5	17	17	100
8,9	31	31	100
8,3	65	65	100
7,6	86	86	100
7,0	152	152	100
6,4	247	247	100
5,7	402	402	100
5,1	643	643	100
4,4	1040	1040	100
3,8	1980	1980	100
3,2	3091	3720	83
2,5	2702	7452	36
1,9	2095	17826	12
1,3	243	45620	1
1,27<	–	94476	0
Total	12834	173797	

4. CONCLUSIONS

The objective of this study was to produce spatial maps of the occurrence of hail and of the diameter of the hail within the areas of Romania, using the forecasts of the WSR-98D radar. A probabilistic approach with maps showing the probability of hail with large diameter, can help the estimation the location and size of the hail. It would not be excluded that if a smaller key step is taken, more edifying results regarding the areas frequently affected by hail could be obtained.

The use of radar data, due to it's fine resolution, both spatial and temporal, is required in order to create a climatology of hail.

Thus, especially during the summer season, when convective processes are more frequent and more intense, convective cells that contain hail are formed in high mountain areas are observed, and the atmospheric circulation (mountain breezes) and orientation of the intramontane corridors allow that at the maturation of intra-convective clouds, they move to the depression areas, hills and plains, where the probability of hail of large diameters to fall increases.

Knowing the mechanism of hail formation, in the more frequently hail prone areas measures can be taken in order to minimize damages in agriculture and industry.

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