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PRECURSOR WEATHER CONDITIONS FOR HAIL-EVENT FORECASTING IN THE MOLDAVIA

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ABSTRACT. The present work analysed a statistically representative number of severe convective events which caused hail and material damage during 1990-2015. For these episodes heights of 0°C, -6°C, -10°C and -20°C isotherms were analyzed. In the layers between these four isotherms, the formation and growth of hailstones occur. The height of these isotherms in the period preceding hail is essential in weather forecast of this phenomenon. Lifted index values recorded before hail events are also correlated with height isotherms. The altitudinal differences between the height of -6°C and -20°C isotherm and freezing level which represents intervals of initiation and formation of hail are identified. Not at last the values of the meteorological indices used to forecast the potential formation and hail falling in extracarpathian Moldavia are presented in details.

Keywords: freezing level, isotherm hight, lifted index, hailstone

1. INTRODUCTION

The most important feature of hail events is the great spatio-temporal variability. The mean number of hail events on extracarpathian Moldavia areas ranges between 0.8 and 1.2 cases per year (Apostol and Machidon, 2009). Characteristics of other dangerous phenomena caused by severe atmospheric instability are presented in regional studies and scientific articles by several authors: Iliescu and Popa (1983), Bogdan and Niculescu(1999The forecast of severe instability is the first step in trying to achieve a medium weather forecast for hail. Many forecast techniques are based on aerological data analysis before hail events. With this data and methods Fawbush and Miller (1953) tried to forecast for the first time the hail size using the temperature, dew point and wind speed. Their method is based on a nomogram that relates CAPE (below the -5° C level) to the observed hail diameter at the groundThe manifestation of severe convections and hail events can be predicted using the instability indices from atmospheric radiosounding. In this regard, detailed studies were conducted by Doswell (2001) , Doswell and Schultz (2006), Brimelow et al. (2002), Manzato (2009, 2011), where usefulness of these indices in the hail forecasting was evaluated.

For short range or ultra-short range forecast of hail information from meteorological radars are also used. For the whole Romania territory, Carbunaru

(2014) and Reckerth (2015) correlated some radiolocation parameters of Cumulonimbus clouds which produced hail falls. In this paper we study the height of key isoterms in the process of hail formation (0^oC, -6^oC, -10^oC and -20^oC), determining their efficiency in forecasting this phenomenon. Also, a great importance for hail forecasting are the altitudinal diferences between -6^oC and 0^oC isotherm, noted with Δ_{H1} and altitudinal diferences between -20^oC and 0^oC isoterm, noted with Δ_{H2}. It was achieved a correlation for the height of these isotherms with the Lifted Index (LI) values recorded on days with hail events. Based on the results obtained through the use of instability indices as predictors of hail, Istrate et al. (2015) attempted to edit a forecast chart of this phenomenon by integrating new thermodinamical parameters.

2. DATA AND METHODS

The data on hail occurrence were taken from specialized sites (http://rda.ucar.edu/datasets/ds463.3/) and mass-media sources (local newspapers). Concerning the hail event occurence, for the period 1990-2014 it was found a total number of 100 cases in which this phenomenon has manifested throughout Moldova. Most data came from weather stations of Romanian Meteorological Administration network and were taken from the NOAA website. Isotherm heights of 0^oC, -6^oC, -10^oC and -20^oC were calculated from radiosounding data from Bucharest Baneasa, Odesa and Cernauti aerological stations. In the first phase were calculated the lapse rates for the interval that includes the necessary isotherms for our analysis.

Under conditions of atmospheric instability the lapse rate (γ) is positive. To determine the vertical thermal gradient, we used formula :

$\gamma = -\frac{\Delta T}{\Delta z}$ where $\Delta T = T_1 - T_2$, $z = z_1 - z_2$, represent increases of temperature and height;

- T_1 – the temperature at z_1 hight,
- T_2 – the temperature at z_2 hight,

To see more accurately the atmospheric conditions in Moldova a mean was calculated for values from aerological stations Bucharest, Chernivtsi and Odessa. Also differences in altitude between $-6\,^oC$ and 0^oC (Δ_{H1}) isotherms and between $0\,^oC$ and $-20\,^oC$ isotherms (Δ_{H2}) were used.

3. RESULTS AND DISCUTIONS

3.1. Temporal frequency of parameters

Structure of hail clouds is very complicated and uneven. There are several types of hydrometeors: water droplets, graupels, hail particles, ice crystals, snowflakes. The environmental variables that influence internal structure of growth layers of hailstone are primarily the water content, which determines the rate of accumulation and the temperature of the cloud. The active layer where clouds are formed is a layer between the free condensation level and the level where the temperature difference between stratification and state curves reaches the maximum value. This level corresponds to the maximum values of ascendent upstream speed located between 600 and 700 hPa (4000- 6000 m), levels in which the -10^{o}C isotherm's altitude varies. The significance of 0ºC isoterm's altitude is important, because coexistence of supercooled water droplets and ice particles initiates the formation of hail at this level.

Three different mechanisms are responsible for the growth of ice-particles. The first mechanism is represented by the collision and aggregation of ice particles, the second mechanism is the deposition, for example water vapor from the particles of ice and the last mechanism consists incollecting and freezing droplets deposited on particles of ice (Delobbe et al., 2002). The -6^{o}C isotherm level becomes essential by corelating it with the maximum reflectivity height of cumulonimbus clouds. In some studies (Abshaev et al, 2008) was underlined that if the height of this reflectivity is above -6^{o}C isotherm level, then the probability of hail is very high.

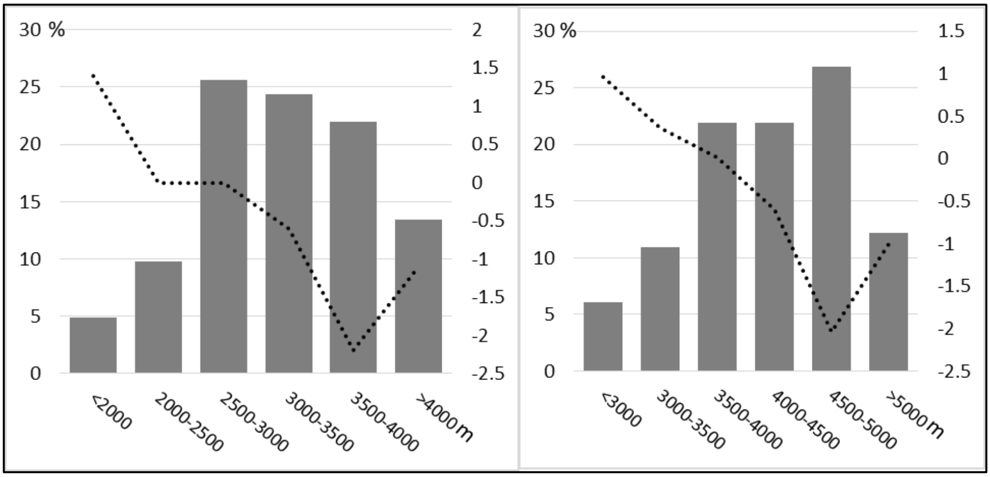

Fig. 1. ***The altitudinal frequency of isotherms heights - columns - (0^{o}C: left; -6^{o}C: right) and corresponding LI values for each altitudinal classes - dashed line - during days with hail***

Following a first analysis of data is seen that the phenomenon of hail occurs mainly when the freezing level height and other studied isotherms are located at certain levels. For values between 3000 and 4000 m of 0^{o}C isotherm and between 4000 and 5000 m of -6^{o}C isotherm hail percentage is over 50% (Fig. 1).

Also it is noticed the coincidence of mimimum values of Lifted Index (LI) at altitude intervals with high frequency. For the two other isotherms heights the situation is similar. Between values of 4500 and 5500 m for -10^{o}C isothermal and 600-700m for -20^{o}C most storms accompanied by hail manifested.

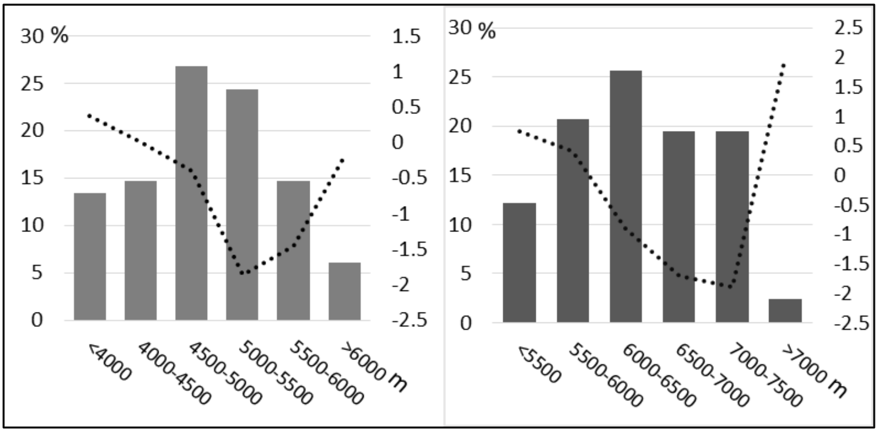

Fig. 2. ***The altitudinal frequency of isotherms heights - columns - (-10^{o}C: left; -20^{o}C: right) and corresponding LI values for each altitudinal classe - dashed line - during days with hail***

Monthly evolution height isotherm is closely correlated with climatic characteristics of the study area. Is noted that the height of the four isotherms increases from May to July-August, the warmest months (Fig. 3).

The altitudinal differences between -6^{o}C, -20^{o}C isothermes and the freezing level it is in a relationship of direct proportionality with the number of hail occurences. Over 80% of hail occurred at $_{\Delta H1}$ values over 800 meters. For Δ_{H2} maximum values coincide with the maximum values of -20^{o}C isoterm. The emergence of this phenomenon took place at values between 2500 and 4000 ΔH2 meters but in most cases exceeded 3000 meters (see Fig. 3).

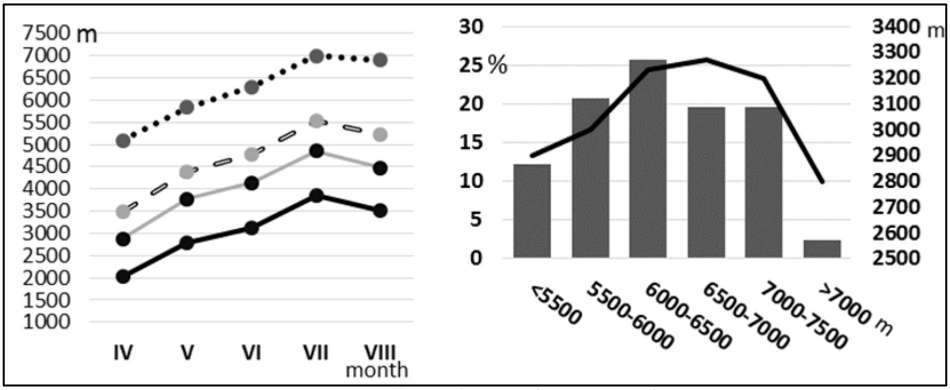

Fig. 3. ***Multianual monthly mean 0^{0}C, -6^{0}C, -10^{0}C and -20^{0}C isotherme altitudes (left), multiannual frequency of -20^{0}C isotherme altitude and mean value of Δ_{H2} (black line)***

3.2. Evaluation of forecast utility

The values of the seven variables, detailed above, can be used to achieve a medium and short term forecasts of hail. The ranges for each variable value describes environmental conditions for most cases of hail with highest capacity of weather phenomenon (Tab 1). Thus, the highest probability of hail is when analyzed isotherms heights have the highest values. Δ_{H2} Δ_{H1} and provides important information related to thermodynamic conditions necessary for the formation and loss of hailstones. High values of these variables describe an area verticaly extended where hail formation and growth occurs.

Amid the existence of a strong upward flow, hailstones can reach impressive dimensions, crossing a wet area of 3000 - 4000 meters. Despite of the high altitude where the freezing level is situated, in many cases it is observed that hail still occurs.

Table 1. ***Parameters values for hail forecasting***

Parameters values							**Hail occurrence probability**
H izo 0°C	H izo-6°C	H izo -10°C	H izo -20°C	Δ_{H1}	Δ_{H2}	Li	
3000-4000	**4000-5000**	**4500-5500**	**6000-7500**	**>1000**	**>3200**	**< -1**	**High**
>4000	**<4000**	**<4500**	**5000-6000**	**800-1000**	**2800-3200**	**-1 and1**	**Moderate**
<3000	**>5000**	**>5500**	**<5000**	**<800**	**<2800**	**> 1**	**Low**

It can be concluded that the size of the hailstone in the cumulonimbus clouds is large enough not to cause total melting downwards in the region with positive temperatures.

Of course there are cases of early hail in April and May when the four isotherms levels are low and also Δ_{H1} and Δ_{H2} values are low. The main characteristic of these early hail is the small size of hailstone but their degree of risk is high due to the fact that crops are in a phenophase when the resistance to mechanical damage is reduced.

For July were carried nomograms which correlates altitude isotherms with Lifted Index value (Fig. 4). This month is recorded most days with hail. Most hail events occurred on days with negative values Lifted index. Also notice a congestion of points between some altitude intervals of isotherms.

4. CONCLUSIONS

The results of this study led to the possibility of creating a table of hail forecast using only data on the height of isothermal and Lifted Index value. Were established certain intervals between which the values of the analysed variables are associated with hail. Generally for high values of isotherms heights and for Δ_{H1} and Δ_{H2}, the risk of this phenomena occurance is the highest. These periods coincide with the lowest mean values of the Lifted Index. We believe that the efficiency of analyzed weather variables in forecast is considerable a first step in complex ways of making a valid approach for extracarpathian Moldavia.

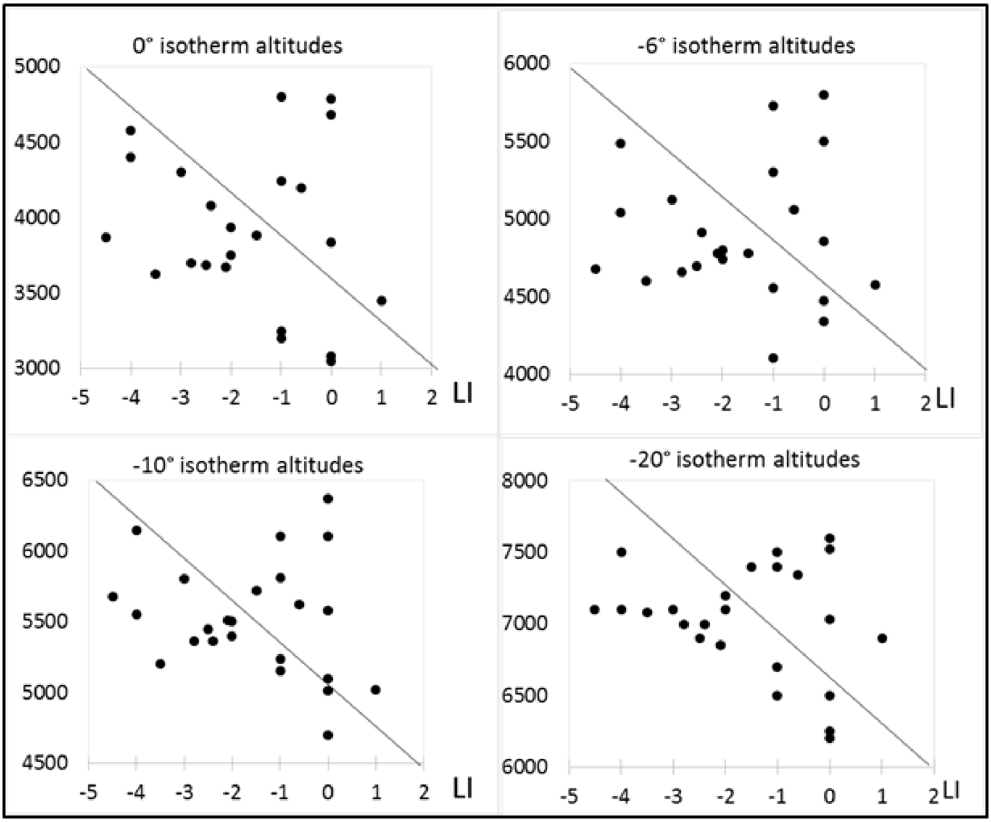

Fig. 4. ***July 0°C, -6°C, -10°C and -2°C isotherme altitudes correlated with Lifted index values during days with hail***

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