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IS THERE A DIFFERENCE IN THE ENVIRONMENTAL CONDITIONS AT THE DEVELOPMENT OF SEVERE AND NON-SEVERE HAILSTORMS OVER BULGARIA?

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INTRODUCTION

The hailstorms are frequent weather hazards across Bulgaria. The prediction of their severity is one of the most difficult issues in weather forecasting. Many authors have analyzed the thermodynamic potential of the environment, responsible for the severe thunderstorms, in particularly hailstorms formation (Doswell and Markowski, 2004; Jewell and Brimelow, 2009; Kunz et al., 2009; Manzato, 2012, etc.). However, the use of determined discrimination threshold values of different environmental characteristics for severity of thunderstorms for a certain region is often unsatisfactory for other geographical areas (Brooks et al., 2003). Therefore it is worth to study whether there is a difference between the environmental conditions at the formation and development of severe and non-severe hailstorms over Bulgaria.

DATA AND METHODOLOGY

The environmental conditions leading to formation of hailstorms in the afternoon, between 1200 and 1500 UTC, during the five years period 2010-2014 were analyzed. The storms developed from April to September over four hail protected areas in Bulgaria. Two of the areas were situated in northern Bulgaria (Vidin and Vratsa districts) and two areas – in southern Bulgaria (Pazardjik and Sliven districts). The hailstorms were classified as severe and non-severe based on sizes of hail stones fell on the ground. The hail stones produced by severe storms had diameter greater than 2 cm in contrast with non-severe, which produced smaller hail stones. The data for hail size are from the rain gauge network of Bulgarian Hail Suppression Agency. For the additional analysis of hailstorm severity, radar data from S-band Doppler weather radars network were used. The average height of cloud tops of the considered severe hailstorms was 13.4 km and maximum height was 15.8 km, while for non-severe storms the values were 11.0 km and 14.8 km respectively. The proximity aerological soundings at 1200 UTC, close to the hailstorms formation were used. The soundings were obtained by the numerical model GFS http://ready.arl.noaa.gov. The mean values, medians, and 10th, 25th, 75th and 90th percentiles of 47 characteristics of the environmental conditions (25 atmospheric thermodynamic parameters, 12 vertical wind shears in various layers, and 10 instability indices) in both samples were considered. Additionally 17 intra-cloud characteristics in both samples were considered too. These characteristics were simulated by 1D cloud model with parameterized microphysics. The discriminant analysis (Softstat, 2001) was applied to establish the ability of analyze parameters to classify the clouds as severe or non-severe hailstorm. The probability of detection (POD) and false alarm ratio (FAR) were calculated for the derived thresholds and classification functions.

RESULTS

The results of our study reveal that among the obtained threshold values of the analyzed environmental characteristics the best skill scores for the discrimination between severe and non-severe hailstorms, developed over Bulgaria have the threshold values of WS_{500gr}=13.1 ms^{-1}, $WS_{850200av}$=14.9 ms^{-1} and WS06=7.6 ms^{-1} (WS_{500gr} is wind shear between the ground surface and 500 hPa level, $WS_{850200av}$ - shear between the mean winds in the 150-300 hPa and 700-850 hPa layers, and WS06 - wind shear in 6 km layer over the ground). Using these threshold values, the probability of detection (POD) of severe hailstorm was 0.82, whereas false alarm ratio (FAR) was 0.40 for $WS_{850200av}$ and 0.44 for WS06 and for WS_{500gr}.

In an attempt to obtain better discrimination between the severe and non-severe hailstorms general discriminant analyses with combination of different parameters were carried out. The best classification functions F (s,ns) which correctly classified severe hail storms versus non-severe hailstorms are:

$$F(s,ns)=0.24* WS_{500gr}+1.92* WBPT_{LCL}-0.21*CIN-1.11* WBPT_{500}+0.42*WS_{850gr}-23.04 \quad (1)$$

$$F(s,ns)=0.61*WS_{500gr}+0.67*WBPT_{LCL}+0.57*ZW_{max}-0.44*WS_{850200av}+0.29*WS_{700150av}-21.77 \quad (2),$$

where CIN is Convective inhibition, WS_{850gr} - wind shear between the ground surface and 850 hPa, $WS_{700150av}$ is shear between winds averaged in the 700 hPa-ground surface layer and 300-150 hPa layer, $WBPT_{LCL}$ is wet bulb potential temperature at the lifted condensation level, $WBPT_{500}$ - wet bulb potential temperature at the 500 hPa level, and ZW_{max} is height of level of maximum vertical velocity simulated by the one-dimension model. At F(s,ns) > 0 the case was classified as severe hailstorm; at F(s,n) ≤ 0 the case was classified as non-severe hailstorms.

The calculated skill scores demonstrate that the forecasting ability of the classification function for the type of hailstorms based on the combination of the CIN, the wet bulb potential temperature and the wind shears (equation 1) is high (POD=0.82 and FAR=0.10). The higher probability of detection of the analyzed severe hailstorms was obtained with the equation 2 - combination of simulated in-cloud characteristic (ZWmax), $WBPT_{LCL}$ and wind shears (POD=0.91 and FAR=0.17).

CONCLUSIONS

Atmospheric thermodynamic parameters and instability indices in days with severe and non-severe hailstorms developed over Bulgaria were analyzed. Our results confirmed that wind shears calculated using averaging wind in various layers are very important (Rhome et al., 2006) and it could be used in determining type of hailstorms (severe or non-severe).

The best discrimination between severe and non-severe hailstorm is obtained using the threshold values of wind shear between ground and 500 hPa - WS_{500gr}, of wind shear between the mean winds in the 150-300 hPa and 700-850 hPa layers - $WS_{850200av}$, as well the wind shear, WS06 in 6 km layer over the ground. However, the single use of any of the mentioned above thresholds leads to raher high FAR.

The performed multiple discriminant analysis showed that the classification function obtained by combination of wind shears, wet bulb potential temperature at LCL and height of level of maximum vertical velocity improves the skill to "predict" the development of severe hailstorms. More than 90% from severe hailstorms were correctly classified and only 17% of non-severe hailstorms were classified as severe using the function in equation (2).

These results demonstrate that "special" combinations of atmospheric thermodynamic characteristics are required for the development of severe hailstorms, indicating that the severe hailstorms are formed in the significantly different atmospheric conditions compared with the non-severe hailstorms. Due to the limited number of the studied cases, the results presented here have to be considered only as a first step to the study of differences between the environmental conditions at the development of severe and non-severe hailstorms over Bulgaria.

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