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The Occurrence of Hail in Selected Location within South Moravia Region in the Period 2003 – 2013

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Abstract

The aim of the study is to characterise hail occurrences in long-term, yearly and daily periods, and evaluation of meteorological conditions, typical for their occurrences in central and south Moravia. The study is based on materials measured and observed at 15 Czech Hydrometeorological Institute's (CHMI) climatological stations in years 2003 – 2013. Daily and 10-minute period recordings of air temperature and precipitation sums have been used. A close attention to rainfall intensity and surface temperature variability in 2 meters layer during the specific events has been paid. Additionally an analysis of storms movement in connection to hail occurrence in particular locations has been done.

The hail appears more frequently during storms than during showers, and approximately a third of hail is accompanied by downpours. The maximum precipitation intensity was between 2.0 mm/min – 4.1 mmm/min in observed locations. A temperature inversion is usually created on the surface level during hail, which for a short time influences microclimatic conditions. In general, hailstorms in Moravia usually come from the west sector and move in east direction. The influence of local terrain morphology on hailstorm is minor, because the hailstorm development is conditioned mainly by synoptic situation in mesoclimate scale.

Key words: extreme weather, precipitation, rainfall intensity, downpour, thunderstorm

Introduction

The climate is often perceived indifferently as we have managed to adapt well to the geographical climatic conditions in the Czech Republic. Extreme weather, including hail, however, evokes considerably more emotions, because of its negative consequences, like property damage, e. g. broken windows and greenhouses,

damaged cars or damaged crop in orchards and fields. Hail also affects other elements of geographical environment like plants, animals and, less apparently, abiotic components. Hail occurrence is characteristic to Moravia region and thus its study requires systematic updating and deeper climatological research.

Hail occurrence, especially its negative consequences, has been a subject to scientific studies since the beginning of the 20th century. “Hail in Moravia in the period 1896 – 1906” (Koutný, 1908) includes a detailed list of dates and hail-stricken places. From newer studies dealing with hail in Moravia region should be mentioned a detailed case study by Šálek (1989) and complex climatological evaluation by Brázdil et al. (1989) and Chromá et al. (2005). Currently, modern database systems collating all the information about hail occurrence and its consequences are created in the world, e. g. American National Weather Service (Gourley et al., 2013) with up to date and also historical information. In Europe there is European Severe Weather Database – ESWD (http://www.eswd.eu) with archive updated with extreme atmospheric phenomena like tornado, severe wind, large hail, heavy rain, funnel cloud, gustnado, dust devil, heavy snowfall/snowstorm, ice accumulation, avalanche, damaging lighting (Krennert et al. 2013).

Materials and methods

We are aware that it is impossible to count and describe all the hail occurrences in such a large area like Moravia, since hail occurs in local restricted areas. The study is based on precise evaluation of hail in specific locations. The subjective method of the occurrences recording has to be taken into consideration and it is supposed the records are not complete since volunteers attend most of the climatological stations. The study is based on hail database prepare from materials measured and observed at 15 Czech Hydrometeorological Institute’s (CHMI) climatological stations Brno region (Fig. 1) in years 2003 – 2013. The studied period is specified based on automatic machines’ homogeneity measurement during past 11 years. For each hail occurrence a detailed characteristic of accompanying meteorological conditions has been drawn. Daily and 15-minute or 10-minute period recordings of air temperature and precipitation sums have been used. A close attention to surface temperature variability in 2 meters layer and rainfall intensity during the specific events has been paid. For the evaluation also image of radar reflectivity have been used and along

with storm records they served for the analysis of convection cell, which have caused hail, and the course of their movement.

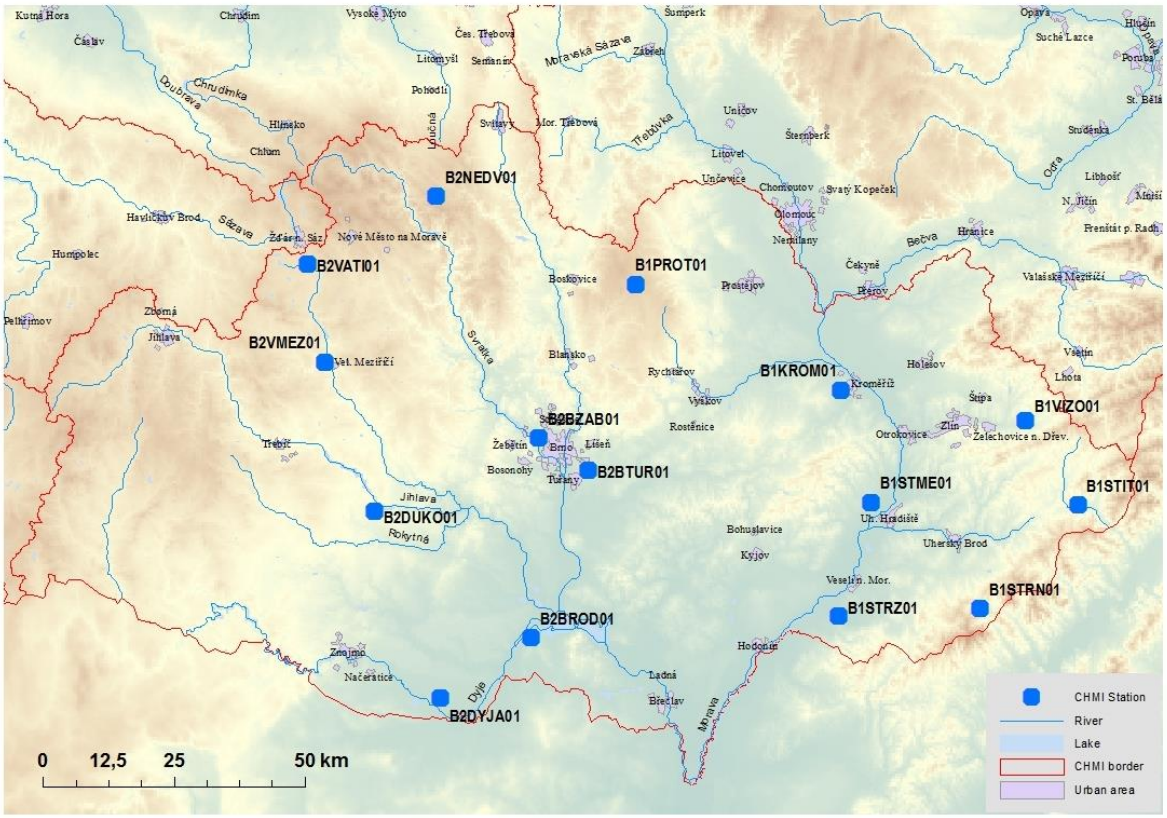

Fig. 1. The location of ČMHI climatological stations used in the study

The aim of the study is to characterise hail occurrences in long-term, yearly and daily periods, and evaluation of meteorological conditions, which are typical for their occurrences in the specific locations in central and south Moravia.

Results

During the evaluated 11 years period, 2 to 3 cases of hail were recorded at the climatological stations in Strání and Staré Město, and up to 27 cases in Vatín (Fig. 2). Relatively small number of hail occurrences was recorded at the stations in Strážnice and Dyjákovice, while in Nedvězí and Velké Meziříčí hail occurred quite often. From the comparison of geographical layout of hail frequency in observed locations can be draw that the east part of Bohemian-Moravian Highlands is hail-stricken significantly more often than Dolnomoravský ravine, The White Carpathians and Dyje River

Valley. This fact is due to the locations altitudes. At the stations in lower altitudes to 400 m the hail frequency is between 2 - 17 cases in 11 years, while in altitudes above 400 m the frequencies is between 12 – 27 cases in 11 years. The hail threshold value in 1 season is 7 cases at the station in Nedvězí, which is located in the highest altitude 722 m. The hail occurrence frequency dependence on altitude was elicited in Chromá et al. work (2005).

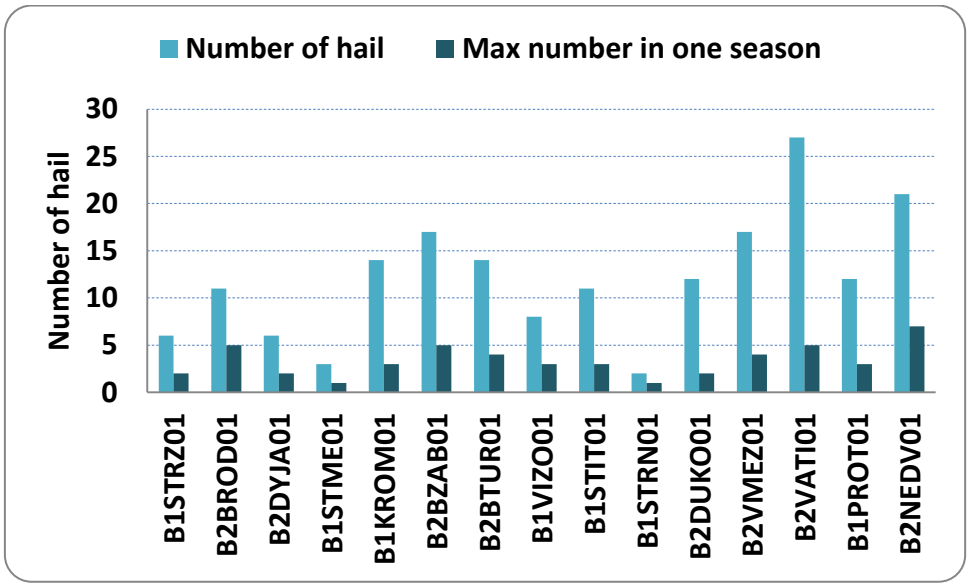

Fig. 2. The number of hail occurrences in selected locations in central and south Moravia in the period 2003 – 2013

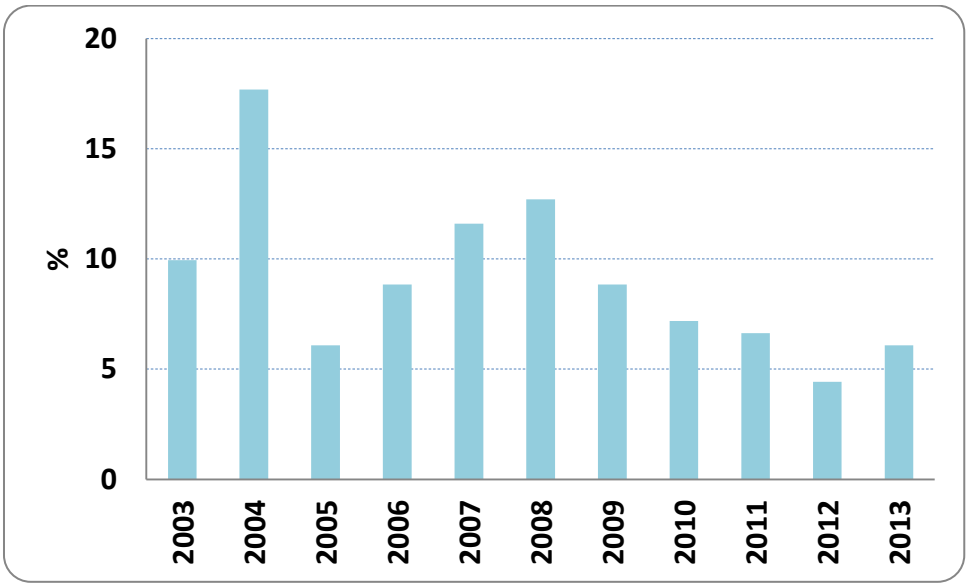

Fig. 3. Hail occurrence frequency in selected locations within central and south Moravia regions in particular years in the period 2003 – 2013

To characterize the hail occurrence all the cases from all the stations were evaluated together. There were 181 events in total. In 2004 hail occurred the most – 17.7% all occurrences (Fig. 3), followed by the years 2007 and 2008. The studied period is unfortunately too short to evaluate trends in long-term changes in hail frequency. According to Brázdil et al (1998) and Chromá et al (2005) studies the number of hail occurrences in Moravia is decreasing.

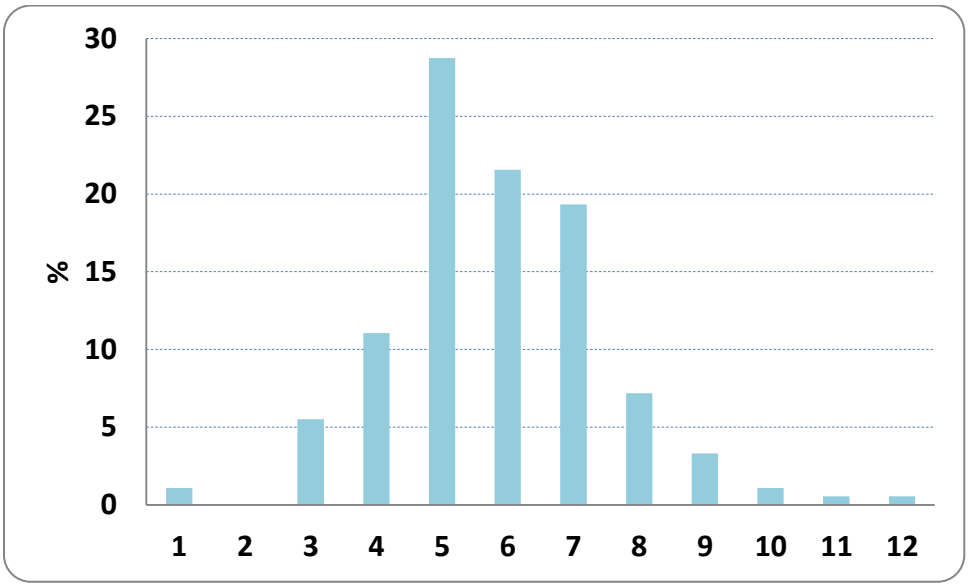

Fig. 4 Hail occurrence frequency in selected locations within central and south Moravia regions in particular months in the period 2003 – 2013

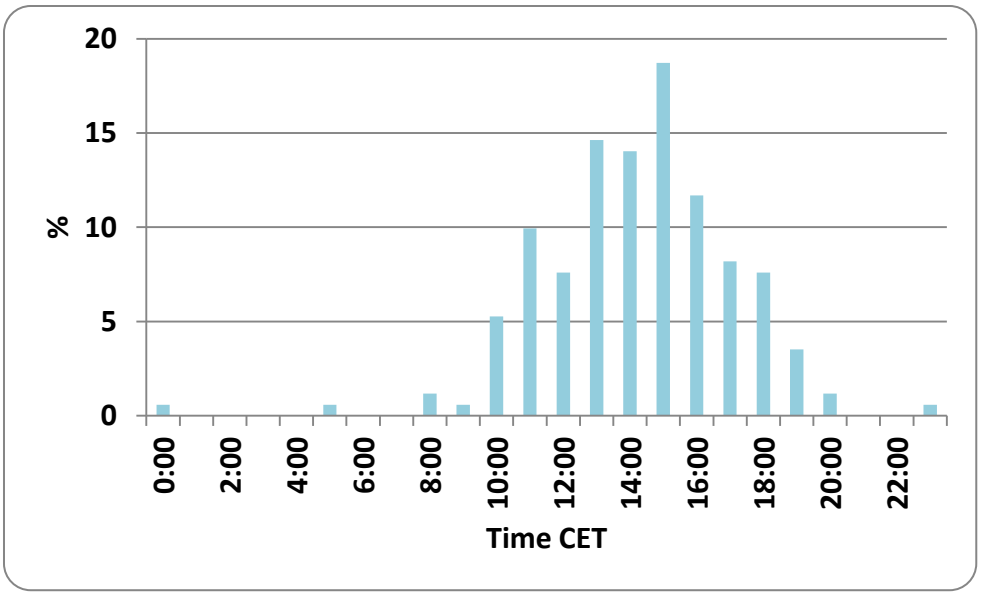

Fig. 5 The time of hail occurrence in selected locations within central and south Moravia regions in the period 2003 – 2013

In a year laps hail appears mostly in warm season – the maximum is in May when 28.7% all cases were recorded (Fig. 4). Similar year cycle is typical for other European regions (e. g. Twardosz et al, 2011, and Bielec-Bąkowska, 2013).

Significant hail occurrence day laps frequency is 1600 – 1700 CET, when 18.7% all cases were recorded (Fig. 5). During night hail occurrences were scarcely recorded. The time duration is usually short and in 68.2% cases not longer than 5 minutes (Fig. 6).

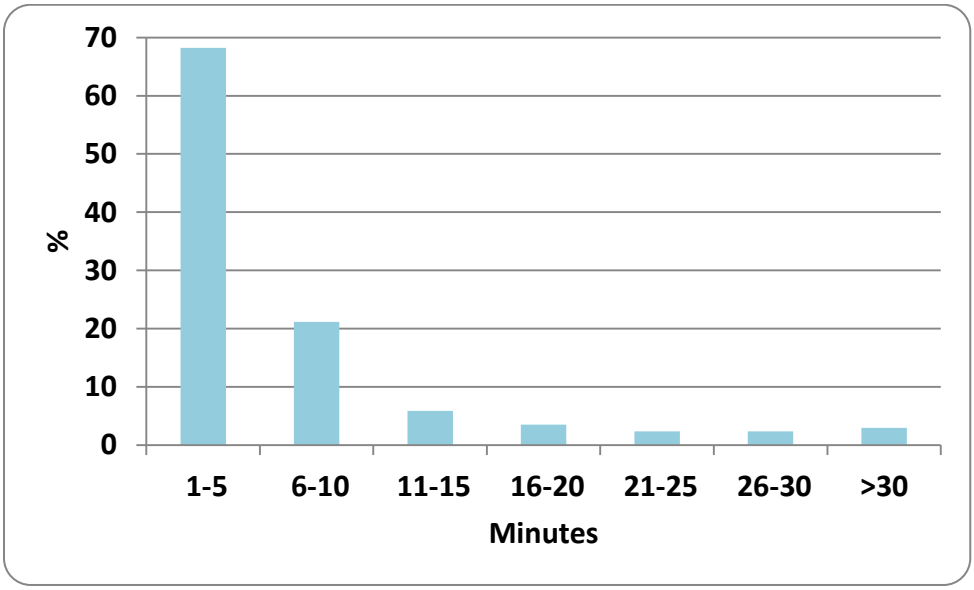

Fig. 6 The duration of hail occurrence in selected locations within central and south Moravia regions in the period 2003 – 2013

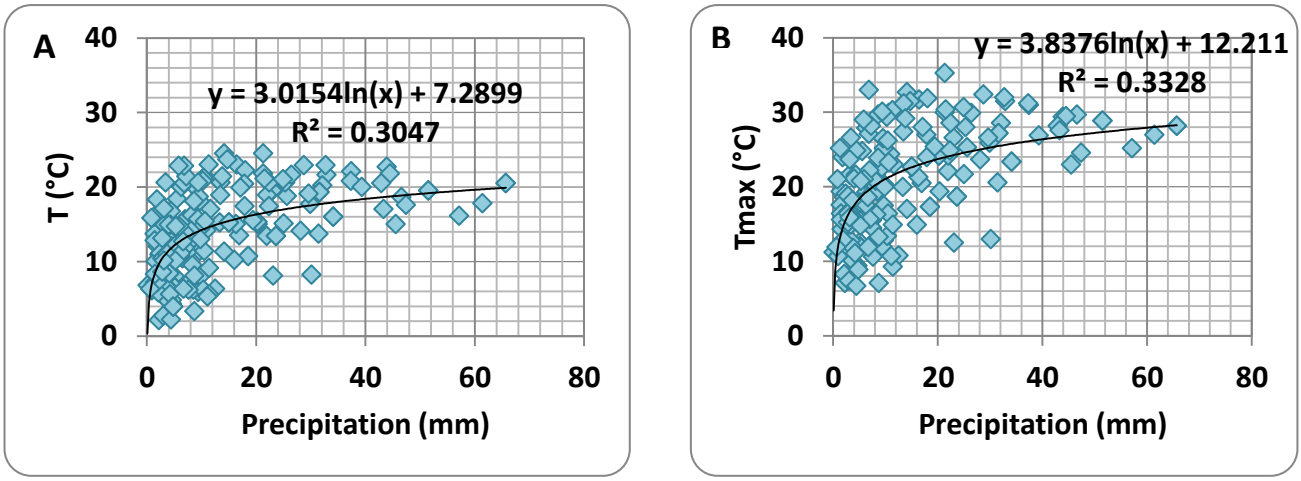

Fig. 7 Average day temperatures and precipitation (A), maximum day temperature and precipitation (B) in hail days (15 ČMHÚ stations, south Moravia, 2003 – 2013)

The following part of the study is focused on characterising meteorological conditions during hail days occurred in general. In this case, all the days were evaluated collectively not differentiating between individual locations. Average daily temperature, maximum daily temperature and average daily precipitation analysis has shown most of the hail occurs in days with average temperature 10.1°C – 20.0°C (in 52.8% cases) and precipitation 0.1 mm – 10.0 mm (53.9% cases), while maximum temperature is 15.1°C – 30.0°C (67.2% cases). A logarithmic dependence between temperatures, both average and maximum, and precipitation was determined in hail days (Fig. 7).

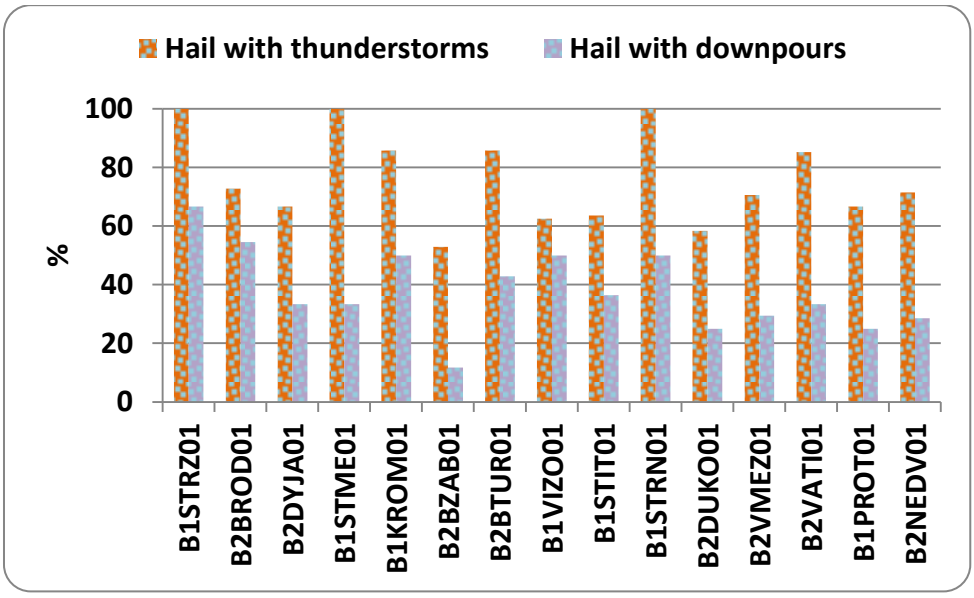

Fig. 8 Thunderstorm and downpour occurrence frequency in days with hail in selected locations within central and south Moravia regions in the period 2003 – 2013

The temperature characteristics correspond to season with most hail days. Should be noted there is rain along with hail. The observed phenomenon is usually dynamic, however, the maximum daily precipitation is scarcely over 45 mm – during the 11 years, there were only 7 such days and of which 3 at station in Vatín. The precipitation is usually not extreme, because the convection cells causing hail are prevalently frontal. Frontal processes are more powerful than free convection processes (Dimitrova et al, 2009). A slow movement of convection cells allows the cells to mature over a particular location and thus increases the potential for downpour (Řezáčová et al., 2007). Using the Wussow method (1922) for evaluation

has been determined in 34.8% hails the precipitation is of downpour character. On the other hand, 73.5% hails are accompanied by thunderstorm (Fig. 8), while the rest by showers.

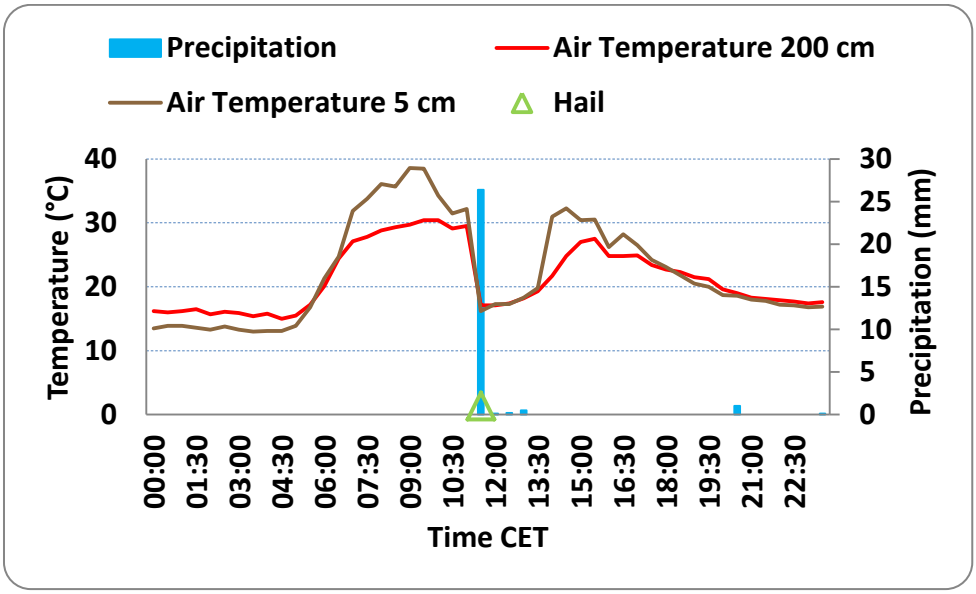

Fig. 9 Temperature and precipitation dynamics at station in Vizovice on 29th Jul 2006

The maximum precipitation intensity was between 2.0 mm/min – 4.1 mmm/min in observed locations. In several cases, the intensity could not been established due to obstruction in rain gauge. During extreme convection phenomena accompanied by strong wind, it is quite common for contamination like leaves, twigs, etc. to get in the rain gauge and bias the measurements.

The detailed analysis of particular hail occurrences, accompanied with the dynamics of surface temperature has shown an influence of hail precipitation on the microclimate in hail-stricken locations. It has been determined during hail there is a rapid drop in temperature both in 5 cm and 200 cm above surface. The rapid drop causes inversion, because the surface, which was hotter than air before the hail occurrence, is intensively cooled by the hail and then adopts the thermal energy from subsurface and upper parts of air. The drop in temperature corresponds with the hail occurrence, or more precisely, follows with a little delay and is by few degrees Celsius. The inversion duration depends on the time of the hail occurrence and the whole precipitation event duration. Around noon, when the sun is up high, inversion

dissolves when hails melt (Fig. 9). During hail occurrences in the evening, the surface is not reheated and thus radiation inversion is formed (Fig. 10).

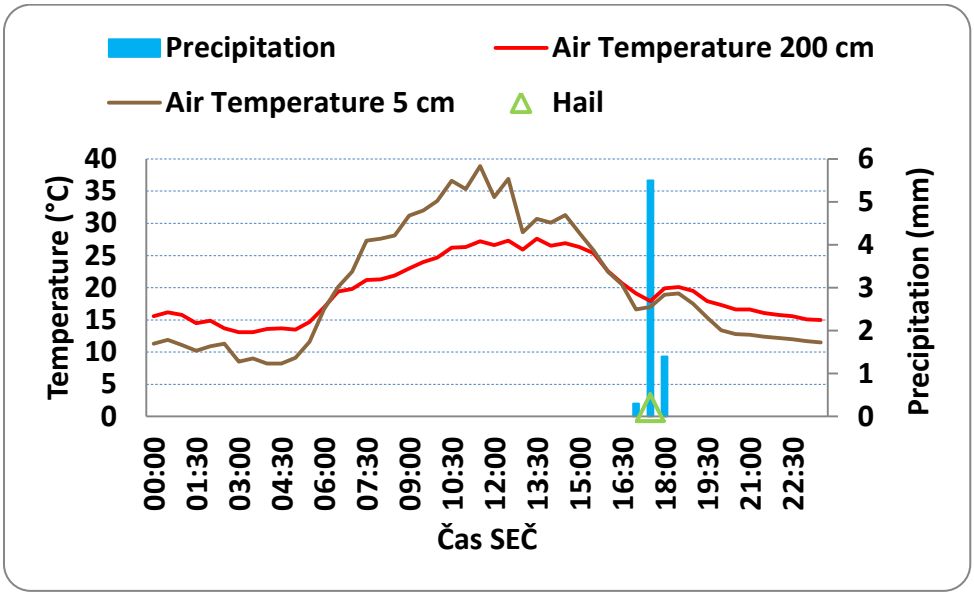

Fig. 10 Temperature and precipitation dynamics at station in Vatín on 18th Jul 2004

To determine whether and how can local conditions influence hail occurrence development an analysis of storms movement in connection to hail occurrence in particular locations has been done. The data was processed based on the volunteers' attending the stations notes.

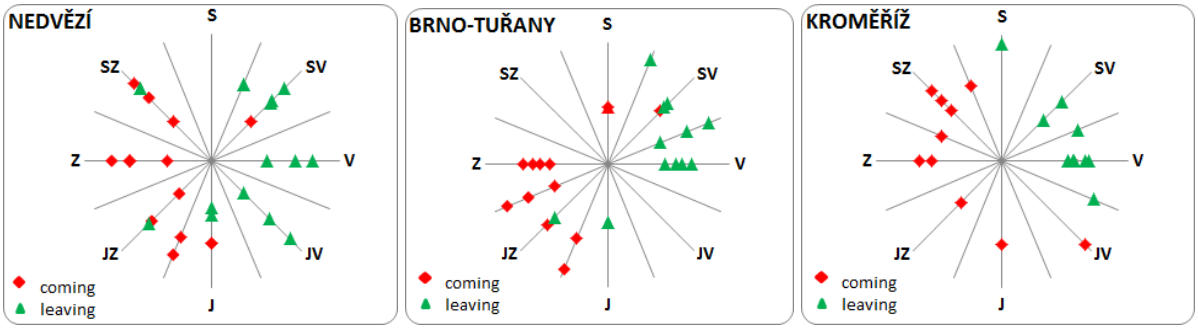

Fig. 11 Hailstorms movement directions at the stations in Nedvězí, Brno-Tuřany and Kroměříž (2003 – 2013)

In general, hailstorms in Moravia usually come from the west sector and move in east direction. It is most obvious at the stations located in Bohemian-Moravian Highlands, where 12 – 15 cases at particular station were examined. Only in few locations it is possible to determine specific dominant directions, e.g. in Brno-Tuřany, where most of the hailstorms come from the southwest continuing to northeast. Other case is a

station in Kroměříž, where hailstorms come from northwest and leave in east direction. Specific case is also the station in Vizovice, where there is a significant dependence on the terrain morphology and hailstorms come from northeast and northwest and leave in southeast and southwest directions. In Dyjákovice hailstorms move in southwest – south – southeast sector. Examples of Nedvězí, Brno-Tuřany and Kroměříž stations are shown in Fig. 11.

However, the observers' subjectivity causes rising of doubts concerning the presented results. In several cases the convection cells movement evaluations, identified by meteorological radar clashes with the observers' notes and have to be evaluated separately. Based on the analysis of selected cases of radar reflectivity, can be concluded, despite the discrepancies, the thesis that hail occurrences are due mesoclimate causes. The influence of terrain morphology is only minor. According to Brázdil et al (1998), storm and extreme weather phenomena is depended on cyclone situation. According to CHMI standardization of weather conditions, hails appear mostly during types: SWc, SWc_2, C, SWc_3 and Wal. The dominance of cyclone situation is due to more frequent frontal storms occurrence than local storms created from heat during anticyclonic situations.

Conclusion

The analysis is focused on time characteristics of hail occurrence and evaluation of the accompanying weather conditions. The results concerning yearly and monthly hail frequency in Moravia are consistent with previous research. The analysis of weather conditions in hail days revealed that hail appears more frequently during storms than during showers, and approximately a third of hail is accompanied by downpours. A temperature inversion is usually created on the surface level during hail, which for a short time influences microclimatic conditions. Analysis of the terrain morphology influence based on the hailstorm development and movement observation has shown that the influence of local terrain morphology on hailstorm is minor, because the hailstorm development is conditioned mainly by synoptic situation in mesoclimate scale. However, the role of hill slope exposition or the characteristics of the surface (water areas, forests, fields, urban areas, etc.) influence on hail occurrence deserve an individual analysis. Acquired knowledge can be useful in

creating local weather forecast concerning extreme atmospheric phenomena occurrences.

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Summary

Cílem práce byla charakteristika výskytu krupobití v dlouhodobém, ročním a denním chodu a také vyhodnocení meteorologických podmínek, typických pro jejich výskyt v konkrétních lokalitách na střední a jižní Moravě. Základem předkládané práci byla databáze krupobití připravená z materiálů naměřených a napozorovaných na 15

klimatologických stanicích Českého hydrometeorologického ústavu (ČHMÚ), nacházejících se na území brněnské pobočky ČHMÚ, zaznamenaných v letech 2003 – 2013. Pro každý případ krupobití byla vyhotovená detailní charakteristika doprovázejících meteorologických podmínek. Použité byly jak denní, tak 10-minutové záznamy o teplotě vzduchu a srážkových úhrnech. Velká pozornost byla věnovaná chodu teploty vzduchu v přízemní dvoumetrové vrstvě a chodu intenzity srážek, během konkrétních událostí. Navíc byla provedená analýza směru pohybu konvekčních buněk, jež způsobily výskyt krup.

Ve zpracovávaném období 11 let bylo na jednotlivých lokalitách zaznamenáno od 2 do 27 případů krupobití. V jednotlivých letech se krupobití vyskytovalo s největší četností v roce 2004, kdy bylo zaznamenáno 17,7% všech případů. Poměrně bohaté na kroupy byly také roky 2007 a 2008. V ročním chodu se krupobití vyskytuje nejčastěji v teplé sezoně, s maximem v květnu, kdy bylo zaznamenáno 28,7% všech případů. Výskyt krupobití má výrazný denní cyklus s odpoledním maximem mezi 16:00 a 17:00 hodinou SELČ, kdy bylo zaznamenáno 18,7% všech případů. V nočních hodinách případy krupobití byly zaznamenaný zcela ojediněle. Doba trvání krupobití je nejčastěji krátká a v 68,2% případů nepřesahuje 5 minut. Analýza průměrné denní teploty, maximální denní teploty a denního úhrnu srážek ukazuje, že většina krupobití se ve střední a jižní Moravě vyskytuje ve dnech s maximální teplotou vzduchu v intervalu 15,1°C až 30,0°C, průměrnou teplotou v intervalu 10,1°C až 20,0°C a úhrnem srážek v intervalu 0,1 mm až 10,0 mm. Po vyhodnocení intenzity srážek metodou Wussowa, bylo zjištěno, že srážky svázané s krupobitím mají přívalový charakter v 34,8% případů krupobití. Maximální intenzita srážek byla naměřená ve sledovaných lokalitách v intervalu od 2,0 mm/min do 4,1 mm/min. Krupobití v 73,5% případů doprovází bouřky a ve zbývajících případech je doprovází přeháňky. V průběhu krupobití dochází k prudkému poklesu teploty vzduchu, jak ve výšce 5 cm nad povrchem, tak i ve výšce 2 m nad povrchem, při čemž vzniká přízemní teplotní inverze. Teplotní inverze dosahuje několik desetin až jednotek stupňů Celsia. Doba trvání takové teplotní inverze závisí na času výskytu krupobití a délce celé srážkové událostí. Pro zjištění zda a jakým způsobem lokální podmínky mohou ovlivňovat vývoj krupobití byla provedená analýza směrů pohybu bouřek, svázaných s výskytem krup v konkrétních lokalitách. Obecně lze říčí, že na území Moravy bouřky nesoucí kroupy přichází většinou ze západního sektoru a vzdalují se k východním směrům. Zkoumaní vlivu morfologie terénu na výskyt krupobití ukázalo,

že krupobití je podmíněné především cirkulačními podmínkami v mezoklimatickým měřítku a role místní morfologie terénu je v tomto druhořadá.

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