SYNOPTIC CONDITIONS OF THE OCCURRENCE OF HAIL IN CENTRAL EUROPE

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I. INTRODUCTION

Hail is not only extremely destructive but also, what makes matter worse, it is difficult to predict or estimate its occurrence in non-urban areas, where weather observations are less dense (Leigh, 2007; Kunz et al., 2009). Average annual hail losses in the USA are $852 million for property and $581 million for crops (Changnon et al., 2009). In Australia, during the last 100 years, this phenomenon was responsible for 11% of building damage, just after tornado cyclones, floods and bushfires (Leigh, 2007).

The main aim of this study is to determine the large-scale synoptic conditions causing hail in central Europe. The motivation for analysing the occurrence of hail in this particular region of Europe grew from the deficiencies of studies and publications, also bearing in mind the fact that this extreme weather event causes multiple damages to agriculture and economy (Leigh, 2007).

II. PRESENTATION OF RESEARCH

The daily data of hail occurrence for 65 stations located in Poland (33 stations) and Germany (32 stations) were analysed in order to distinguish spatial and seasonal distribution of hail frequency in central Europe and they were derived from the Institute of Meteorology and Water Management (IMGiW) and Deutscher Wetterdienst databases (Figure 1). The period of study spans 1966-2010, covering the warm season from April to September. The limitation of the research area only to those two countries was due to the lack of complete and correct data series for such a long period of observations, as vast majority of them cover no more than 15 years.

The analysed sector of central Europe was divided into 5 smaller regions, characterised by similar seasonal hail variability within each of them for which purpose the Ward's method of hierarchical clustering was used (Figure 2). The regionalisation was necessary because of the size of the study area and, consequently, the differences in the weather and climatic conditions, such as air temperature, direction of air mass influx, or the continentality/marity of climate. This method is appropriate for analyses where the number of clusters is unknown and where samples are relatively small. The aim of using this cluster analysis was to group observations or variables into clusters based on the high similarity of climatologic features, where the input data matrix consisted of the stations as variables and the number of hail days in pentads of warm season being the cases.

At each cluster of stations synoptic conditions of hail occurrence were determined. For that purpose daily mean sea level pressure (SLP) and 500-hPa geopotential height (500gh) obtained from the National Centers for Environmental Predictions (NCEP) – National Center for Atmospheric Research (NCAR) reanalysis (Kalnay et al., 1996) were used. In order to indicate the differences between the synoptic conditions during the days with hail and seasonal means (April-September) anomalies of the parameters described above were computed.

Although hail is widely recognised as a very local, rare and short-term phenomenon over central parts of Europe, some temporal and spatial characteristics were identified.

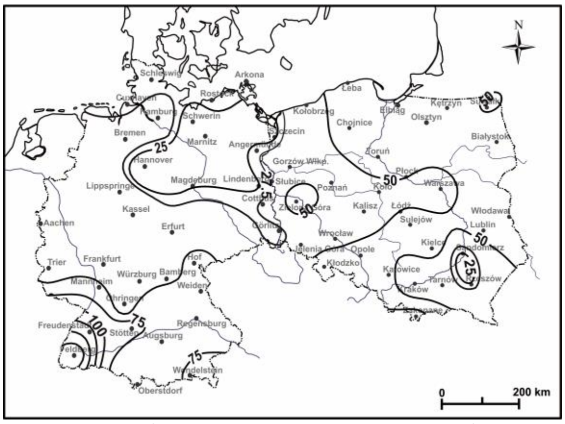

FIG. 1: Number of days with hail during the warm half-year 1966-2010 and location of the synoptic stations in central Europe.

III. RESULTS AND CONCLUSIONS

During the years 1966-2010, 3148 hail events were reported, 65% of which occurred during the first half of the warm season (April – June), with May as hail peak month. The mean monthly number of hail days in this multi-year ranged from 4.5 day in September to 15.3 days in May (Table 1).

	IV	V	VI	VII	VIII	IX	IV-VI
Sum	542	842	684	500	334	246	2068
Seasonal mean	9.9	15.3	12.4	9.1	6.1	4.6	37.6
Share (%)	17.2	26.8	21.7	15.9	10.6	7.8	65.7

TABLE I: General characteristics of hail occurrence in central Europe.

The highest number of hail days can be observed in the highlands of southern Germany. At least 50 days with hail were recorded in the lake region in north-eastern Poland. Hail occurred least frequently in the eastern part of the German Lowlands (Figure 1).

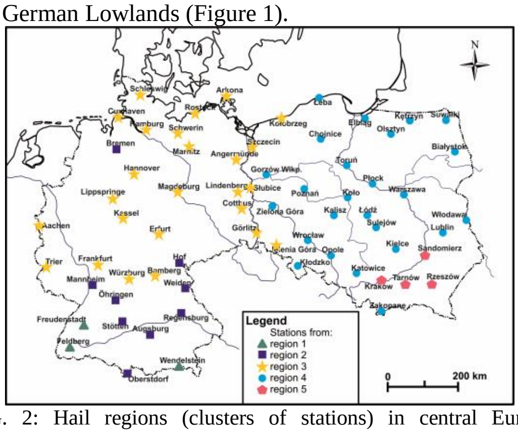

FIG. 2: Hail regions (clusters of stations) in central Europe according to Ward's method.

Considering the temporal variability of hail occurrence in the pentads of the warm season, 65 stations were divided into five separate hail regions (cluster of stations) (Figure 2). The highest number of hail days was recorded in region 1 (>20 days with hail from May to August). Hail appeared least frequently in the lowland part of Germany reaching 5.7 days with hail in May. In most regions hail-peak month was May, except for region 2, where the maximum number of hail days occurred in June (12.2). In all regions hail occurred least frequently in September.

Considering the significant influence of atmospheric circulation on the conditions and processes taking place in the over-ground layer of the atmosphere, the occurrence of hail was analysed in the context of SLP and 500gh variability within the troposphere (Figure 3).

The most typical conditions for hail occurrence in central Europe are the negative anomalies of the sea level pressure and the depression of 500-hPa geopotential heights over the European continent, usually with a low pressure system and the disturbance in zonal influx.

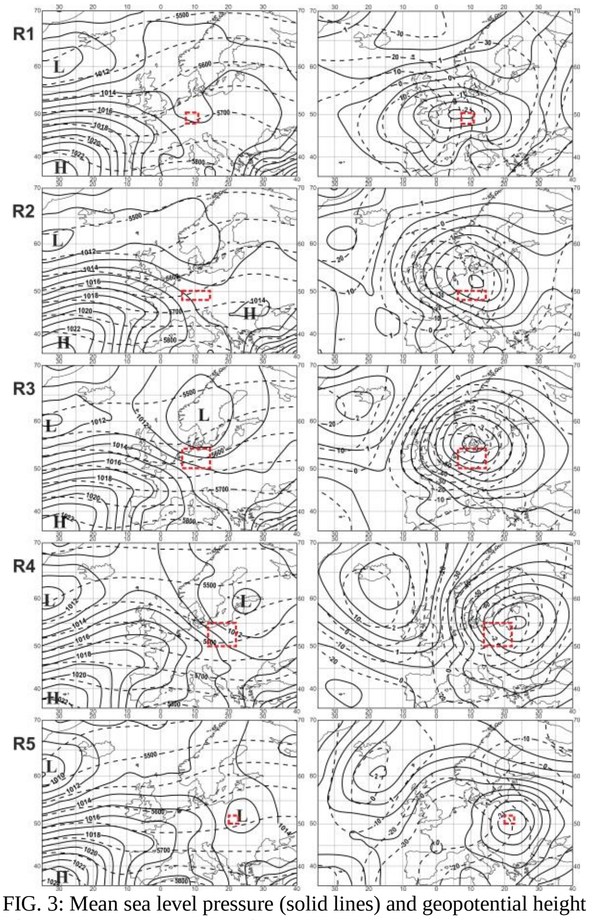

FIG. 3: Mean sea level pressure (solid lines) and geopotential height of 500 hPa (dashed lines) (left column) with anomalies (right column) for the days with hail at each cluster of stations.

All the same, the necessity of regional divisions in climatology is confirmed by the variation of the atmospheric circulation conditions specified for each region as the location and intensity of the anomalies may differ.

Hail in mountainous region 1 can be associated with less negative sea level pressure anomalies and no distinct pressure system over Europe. The positive anomalies of 500-hPa geopotential height indicate the presence of a warmer air mass. The remaining part of the German uplands, marked as region 2, was within the negative anomalies of both the sea level pressure and the 500-hPa geopotential height, but their centres were at a considerable distance indicating the dynamic movement of the pressure system to the west. These results correspond to the observations of Kunz et al. (2009), which have proven that hail in southern Germany can be caused by either a higher pressure over central Europe or a low with fronts in the northern sector of Europe. The lowland part of the research area (regions 3 and 4) owed the hail precipitation to the presence of a more distinct low pressure system over the Scandinavian part of Europe and, more importantly, to the strong negative sea level pressure and 500-hPa geopotential height anomalies. The centres of the anomalies do not coincide which implies the eastern direction of movement of the pressure system.
Region 5 was characterised by the most clear baric situation with a shallow low pressure system and the centre of negative SLP anomalies over the south-eastern part of Poland (Figure 3).

IV. ACKNOWLEDGMENTS

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