Hail climatology of Sofia-city district in Bulgaria

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The geographical location and diverse terrain of Bulgaria characterize it as one of the most hail-stormy countries in Europe. Historical results as well as recent research show a notable territoriality of hail precipitation in Bulgaria. The number of days with hail are more frequent in the southwestern mountainous part of the country, especially in districts Sofia-city and Sofia region, according to estimation of mean annual number of hail precipitation days in one station over the period 1961-2015 (see Fig. 1). The Sofia-city district is the smallest one among the other 27 districts in Bulgaria with area of about 1, 344 km^2, but here live more than 25% of all Bulgarian population. From the beginning of 21 century the values of reported damages caused by hail precipitation in Sofia-city district increases. According to insurance data only severe hailstorm on 08 July 2014 cased damages for more than 123 million euro (Viktor E. et al., 2015).

The aim of the study is to present spatio-temporal variation of hail events in Sofia-city district during the period 1917 - 2016. The study is carried out on the basis of meteorological data concerning hail fall events for 16 climatological and rainguage stations from the meteorological network of the Bulgarian National Institute of Meteorology and Hydrology (NIMH), who worked continuously at least 60 years from the 100-years period of study and are with altitude below 800 m (Fig.1). Part of information from rainguage stations for the period 1917-1990, which was available only in paper form, was entered into computer-compatible form and the rest of it was taken from meteorological data base of NIMH. All stations were selected according to the quality of observations. The hail precipitations are recorded only when they occur in limited site where the weather station is located and so their frequency seems to be under-evaluated in the recent times. In this study only data from visual observation are used.

According to meteorological station data 1534 hail precipitation events in 963 days are registered during the 100 year period of investigation. About 79% of them are observed in warm half of the year between April and July. All hail precipitation events are also classified by duration and severity and most powerful of them are presented. Considering the phenomenon duration 237 days are determined as wide-spread convective events in which the hail precipitation is registered in at least 2 meteorological stations. The estimation of these hazardous cases is supported by the information from Annual Weather Almanac of meteorological service, monthly bulletin of NIMH and media reports. In order to investigate more precisely the risk of severe hydrometeorological events, it is necessary to build national database including the damages caused by the different hazardous events by sectors of economy.

Annual distribution of hail days

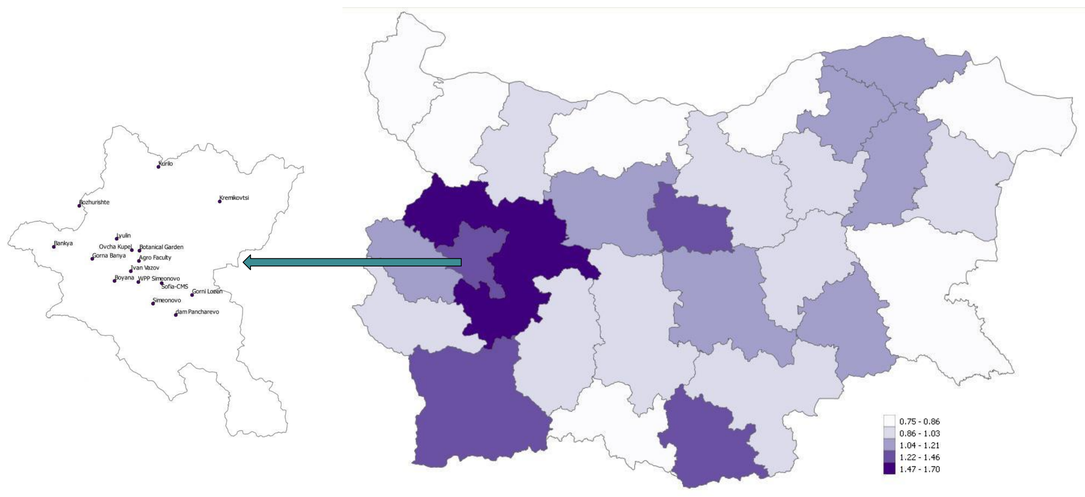


Figure 1. Mean annual number of hail days for one station from non-montaunious areas of each district in Bulgaria (1961-2015) and distribution of meteorological stations in Sofia-city district (left part), which are used in the study

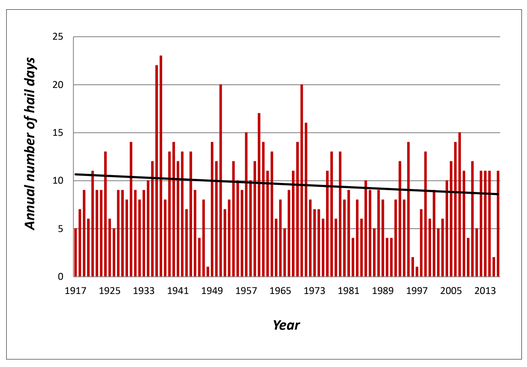


Figure 2. Annual distribution of days with hail precipitation in any station in Sofia-city district during the period 1917-2016

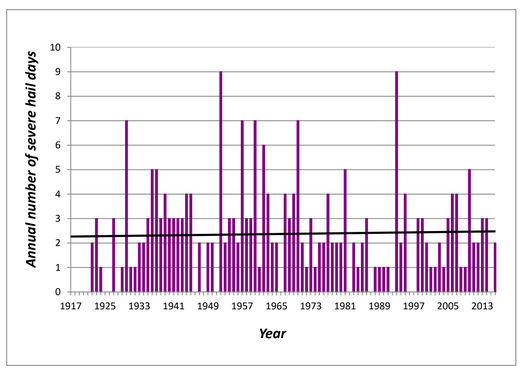


Figure 3. Annual distribution of days with hail precipitation at least in 2 stations in Sofia-city district during the period 1917-2016

Negative trend in annual distribution of hail-days is observed for Sofia-city district during the 100 years period of investigation (Fig. 2). The same tendency was reported for whole country for the period 1961-2010 (Bocheva&Simeonov, 2015), as well as for many countries from Europe (Sioutas et al., 2009; Svabik, 2011) and also for some regions in USA (Changnon&Changnon, 2000), China (Xie et. al, 2008) and Argentina (Mezher et al., 2012). In the same time a slightly positive trend in annual distribution of wide-spread hail events during the period 1917-2016 is observed (Fig. 3). The statistical significance of their changes is calculated by the Mann-Kendall test. The results show than both trends are statistically insignificant.

- Maximum annual number of hail-fall days is registered in **1937 (23 days**/available data from 6 stations**)** and minimum – **1997 (1 day**/10 stations)
- Maximum annual number days with wide-spread hail events is **9 days** –**1952**/16 stations and **1993**/14 stations

Monthly distribution of hail days

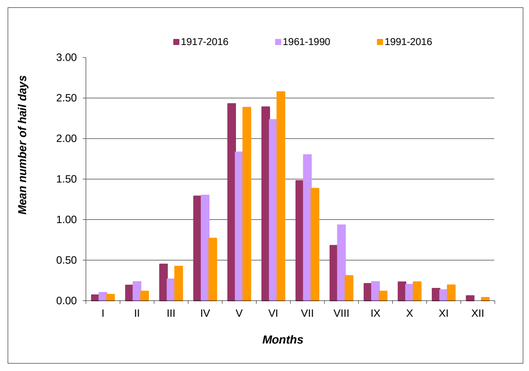


Figure 4. Mean monthly number of hail precipitation days in any station in Sofia-city district

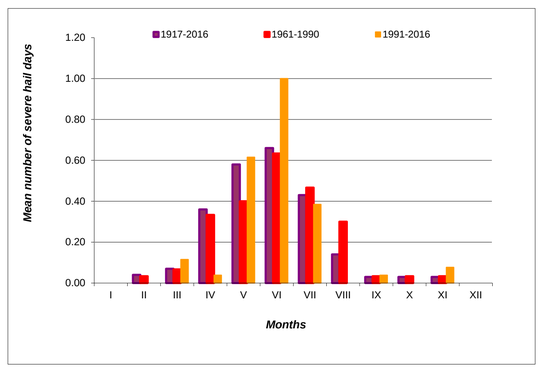


Figure 5. Mean monthly number days with of hail precipitation days, registered at least in 2 stations during the same convective process

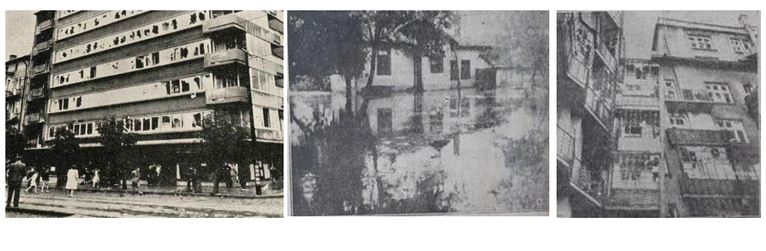
- About 90 % of all hail events occurred during the period March – August.
- **1917-2016** - The maximum number of days with hail is registered in **May and June (2.4 days).**
- **1961-1990** - The maximum number of days with hail is registered in **June (2.2 days),** followed by **May and July (1.8 days)**
- **1991-2016** -The maximum number of days with hail is registered in **June (2.6 days),** followed by **May (2.4 days)**
- About 90 % of wide-spread hail precipitation days occurred between months ***April and August*** for periods **1917-2016** and **1961-1990**. For period **1991-2016** - 88% of severe convective cases was between ***May and July.***
- **1991-2016 (SPRING)** - More pronounced increment of wide-spread hail events is observed in March **(about 70%)** and decrement in April **(about 88 %)**.
- **1991-2016 (AUTUMN)** – The number of wide-spread hail days increases in September **(about 33%)** and November **(about 170 %)** in comparison with other periods.

The analyse of duration of hail precipitation events show that about 30% of them are with indefinite durations and interruptions; 26% are with duration up to 5 min; 27% with duration between 5 and 10 min; 8% - between 10 and 15 min and about 10% between 15 and 40 min.

Almost all wide-spread hail precipitation events have a duration above 5 min.

Wide-spread hail precipitation events present about **25% (237 days)** of all hail days and **18 % (41 days)** of them are connected with torrential precipitation and/or strong wind. These combination of convective induced phenomena often lead to local floods, significant material damages and sometimes casualties.

01 July 1941



Between 16:00 and 16:30 local time (LT) a violent hail storm hit Sofia. According to meteorological station data and media reports the hail path was with length about 20-25 km and with more about 5-10 km and passed. The reported size of hail stones was about hen egg. The storm passed trough the central parts of the city. The severe hail and rain caused great damages on infrastructure, gardens and buildings – many broken windows, mainly on north and northwest sides of the houses and broken roofs. More than 60 % of crops and plants in the region were destroyed.

14 August 1986

Powerful thunderstorm, accompanied by hail (size like hazelnuts) and torrential rain passed through Sofia from west to east. Meteorological stations from central part of the city reported for precipitation amount about 23 mm/25 min. Many streets and stores from central and eastern parts were flooded. According to newspapers "Sofia looked like Venice after 15 min summer shower".

08 July 2014

The giant hail stones in Sofia had diameter up to 10 cm size and irregular shape. The hail path was with length about 30 km and width more than 10 km and passed trough the central parts of the city. According to meteorological station data the duration of continuous hail was about 25 min and measured precipitation amount during the process was above 35% of monthly normal. The severe hail and rain and very strong wind caused huge damages to the infrastructure, buildings and vehicles. More than 40 people were injured by hail stones or broken windows in Sofia. One man was killed by a falling tree.

17 June 1969

The severe convective storm hit different parts of Sofia between 13:00 and 16:00 LT. More affected were western and south-western regions of the city, where hail with size like nut caused great damages in gardens and torrential rain flooded many streets, stores and ground floors of some buildings. In Lyulin measured precipitation amount during the process was 113 mm (150 % of monthly normal)

22 May 2012

The severe convective storm hit many regions of Sofia between 14:30 and 16:00 LT. More affected were western and central parts of the city, where severe hail caused great damages in gardens. Torrential rain with duration about 20-30 min caused floods, mainly in central parts of the city. The severe hail and very strong wind caused damages to the buildings and vehicles.

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