

**LONG-TERM VARIATION AND ANALYSIS OF HAIL PRECIPITATION IN SOFIA REGION**

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**Abstract**

Bulgaria is one of the most hail-stormy countries in Europe because of its geographical location and diverse terrain. Climate studies show a notable territoriality of hail precipitation in Bulgaria. According to some researches, the number of days with hail was more frequent in the southwestern mountainous part of the country, especially in districts Sofia and Blagoevgrad.

The Sofia-city district is the smallest one among the another 27 districts in Bulgaria but is the most densely populated area in the country. From the beginning of 21<sup>st</sup> century the values of reported damages caused by hail precipitation in Sofia increased. According to insurance data, only severe hailstorm on 8 July 2014, which hit mainly central parts of the city, caused damages for more than 123 million euro.

The aim of the study is to present spatial and temporal variation of hail events in Sofia-city district during the period 1917 - 2016. According to meteorological station data 963 hail days are registered during the 100 year period of investigation and 72% of them is 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 analyzed. For estimation of these hazardous cases the available information from media and insurance companies are used.

*Key words: hail climatology, annual distribution, severe events*

**Introduction**

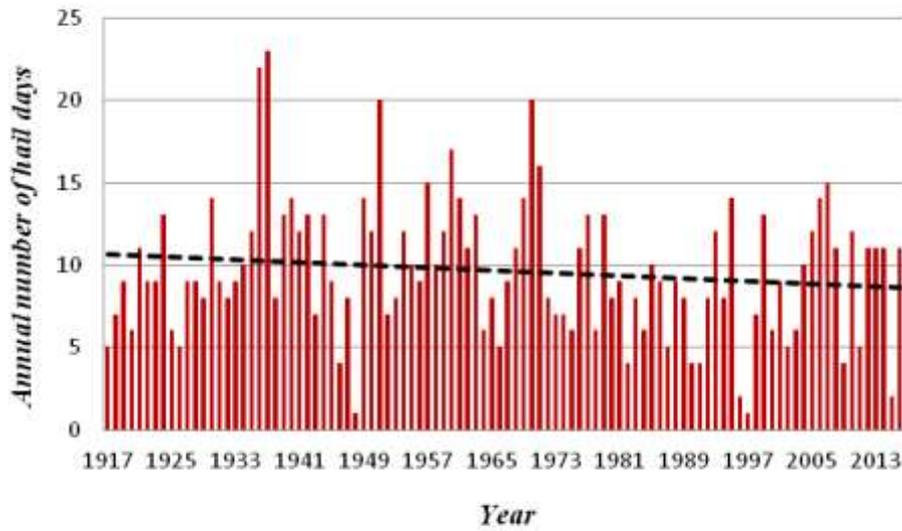
The regions with the highest frequency of hail events in Northern Hemisphere are located in North America (along the Rocky Mountains from Alberta in Canada to New Mexico) and in Europe (from northern part of Pyrenees, trough Central Europe and the Balkans, to the northwest to Caucasus). In some Central European countries like Germany, Switzerland and France, the hail damages on buildings, vehicles and crops are estimated at several million euro per year (Mohr and Kunz, 2013). In Cyprus, it is found that during the period 1996-2005, 91% of losses in agriculture are due to hail precipitation (Nikolaides et al., 2009). The same increasing tendency in severity and frequency of hail storms is observed in Bulgaria during the last 20 years (Gospodinov et al., 2015; Bocheva et al., 2018). According to many climate studies from for different periods (Stanchev, 1964; Bocheva and Simeonov, 2015), the highest frequency of hail precipitation is observed in southwestern mountainous region of country, for which belong Sofia-city district.

The aim of the study is to present spatial-temporal variation of hail events in Sofia-city district during the period 1917 - 2016. The Sofia-city district is the smallest one among the other 27 districts in Bulgaria with area of about 1, 344 km<sup>2</sup>, but here live more than a quarter of all Bulgarian population. So any severe convective storm, associated often with huge hailstones (with diameter more than 20 mm) and strong winds, which hit even a part of Sofia, is able to cause significant property damages. In this study a brief analysis of more severe hail events over the city is also presented.

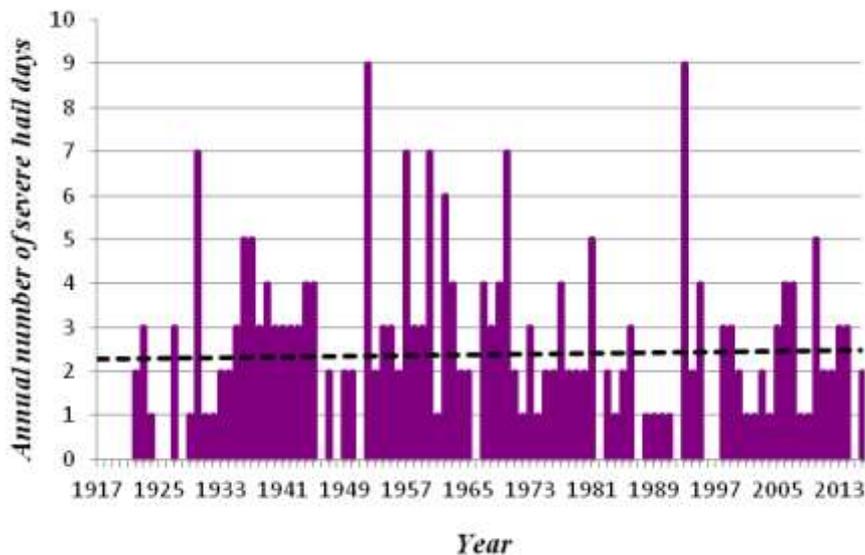
**Data and methods**

The study is carried out on the basis of meteorological data concerning hail fall events for 16 climatological and rainauge stations from the meteorological network of the Bulgarian National Institute of Meteorology and Hydrology, which worked continuously at least 60 years from the 100-years period of study and are with altitude below 800 m (Fig.1). They are selected according to the





**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

**Monthly distribution of days with hail precipitation**

The analyses of hail events show that about 90 % of all occurred during the spring and summer between March and August. The maximum number of days with hail precipitation during the 100-years period of investigation is registered in May and June (2.4 days) – see Fig.4. According to previous investigation (Bocheva and Simeonov, 2015) hailstorms are more frequent in May and June in all parts of Bulgaria. The very similar intra-annual distribution of hail events is established also for other Balkan countries (Pocakal et al., 2009; Sioutas et al., 2009), while for the countries from West and North Europe this maximum is a month later in July (Tuovinen et al, 2009; Berthet et al., 2011). For two other investigated periods the summarized monthly distribution of hail events is almost the

same – with pick in June (2.2 days for period 1961-1990 and 2.6 days for recent period 1991-2016 – Fig. 4).

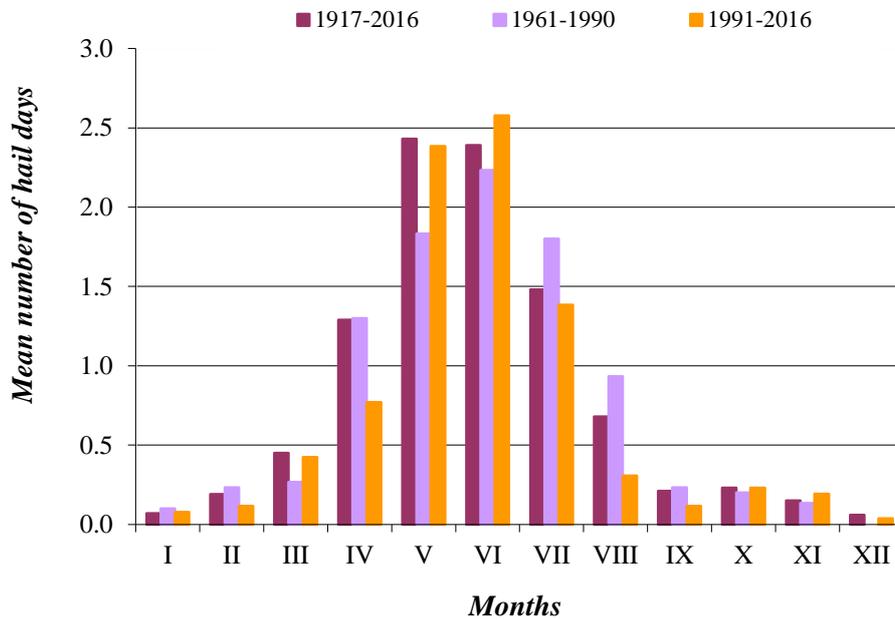


Figure 4. Mean monthly number of hail precipitation days in any station in Sofia-city district

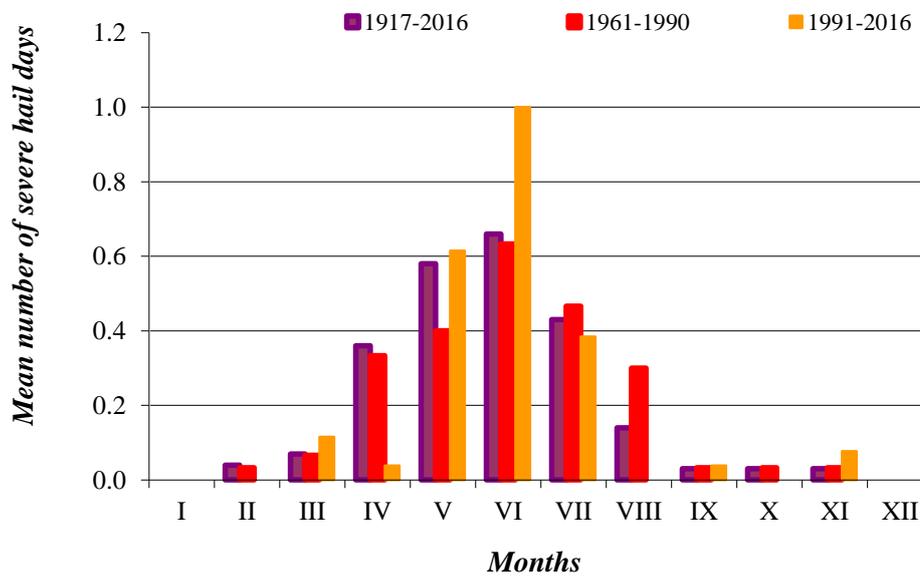


Figure 5. Mean monthly number of hail precipitation days, registered at least in 2 stations during the same convective process

Severe hail precipitation events are about 25% (237 days) of all hail days in Sofia district during the 100-years period of investigation. Their monthly distribution is presented on Fig. 5. About 90 % of them occurred between months April and August for periods 1917-2016 and 1961-1990. For the recent period (1991-2016) the monthly distribution of wide-spread hail events is concentrated in 3-months interval – 88% of all cases are registered between May and July. Moreover, in April a significant decrease with more than 80% is observed, while the opposite tendency in relatively cold

months like March and November is observed (Fig. 5). In March the number of wide-spread hail precipitation events increase with 70 % and in November this increment is about 170 % during the last period 1991-2016.

### Estimation of duration of hail precipitation events

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 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 on the same process according to meteorological station data. These combinations of convective induced phenomena often lead to local floods, significant material damages and sometimes casualties. According to meteorological data, information from newspapers and other media and brief data from insurance sector, at least 2-4 such type severe hailstorms took place in each decade from the period 1917-2017.

For example, one of the most powerful recent severe hailstorms hit Sofia on 08 July 2014 and according to the data from the insurance companies the reported damages was for more than 123 million euro. The giant hail stones in Sofia had diameter up to 10 cm size and irregular shape (see Fig. 6). The hail path was with length about 30 km and width more than 10 km and passed through 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 (Fig. 6). More than 40 people were injured by hail stones or broken windows in Sofia. One man was killed by a falling tree.



**Figure 6.** After 30-minutes severe convective storm, which strike Sofia on 08 July 2014

### Conclusions

- According to meteorological station data for the 100 years' period of investigation, the mean number of days with hail precipitation for Sofia-city district is about 9 days/year.
- About 90 % of all hail events occurred during the period March – August.
- During the last 26 years increase in number of days with severe hail events is observed in un typical months March (70%) and November (170%).
- Recently the 88% of severe hail storms is registered between May and July.
- All severe hail events have duration more than 5 min. About 20% of them are connected with showers and/or strong wind.

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