HAILSTONE-TO-HAILSTORM RELATION IN NORTHERN GREECE

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I. INTRODUCTION

Hailpads constitute the commonest method of hailfall studies on a global scale, both in research and operational programs (Changnon and Towery, 1972; Strong and Lozowski, 1977; Dessens, 1986). Hailfalls in the region of Central Macedonia show a space-time variability, as well as a limited availability of actual observations. A hailpad network, consisting of about 140 hailpads, installed in this area, is used to better display the intensity and areal coverage of hail activity. Objective operational parameters can result from a hailpads examination, like days with hail on ground (hail days) and the number of hailpads hit for each hail day.

II. PRESENTATION OF RESEARCH

Collected pads are checked the day following a storm day to confirm a supposed hailfall. The limits of storms' track are easily extracted with the aid of the radar recording system (TITAN). Hailpad data cover the period 1984-2008, from April to September, with the exception of years 1991, 1994-95 and 2003, that is a total of 21 years. Since the exposure period of the network varied between 126 and 183 days, normalized monthly averages were taken into account for the months of April and May.

Since the limits of the area of study varied from time to time, with a subsequent addition of new hailpads, normalized averages were taken also into account, so that the mean frequency of hail occurrence at the site of each pad represent correctly the years of each pad's exposure. A percentage of 80% of hailpads were exposed for the entire period.

The data used in this study are: the hailfall date, the location of hailpads hit, the number of hailstones on each hailpad hit and the diameter of the biggest hailstone on each pad hit. The storm that produced a certain hailfall was identified with the aid of the digital radar recording system. Physical characteristics of hailstorms were also used, like its maximum reflectivity and maximum top height, as well as the time of storm onset. Seeding data were finally used, namely whether a certain hailstorm had previously been seeded or not. A total of 198 hail days, 369 hailstorms and 1081 hailpads hit was recorded.

The spatial distribution of hail occurrence, normalized according to the years of exposure of each hailpad appears in Figure 1. Five frequency classes are distinguished, and neighbouring sites belonging to the same class are enclosed within the same isopleth. The maximum frequency of hail occurrence is found in the north part of the area, with the absolute maximum to the northwest. The effect of topography is obvious: hail maxima occur in high terrain locations, while minima in plain and coastal areas. Similar results were obtained by Sioutas et al., 2009 in an independent study.

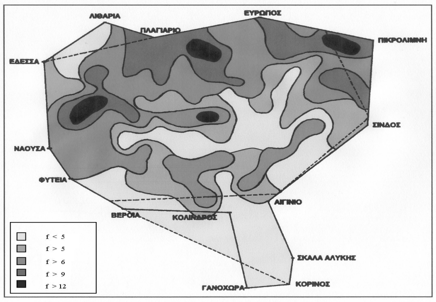

FIG. 1: Spatial distribution of hail occurrence in Central Macedonia, Greece.

Figure 2 shows the time series of the number of hail days for the period of study, in which the dashed line represents the mean value and the continuous line the trend, which is increasing, implying a tendency towards extreme phenomena. A similar distribution and trend was found for the number of hailstorms and of hailpads hit.

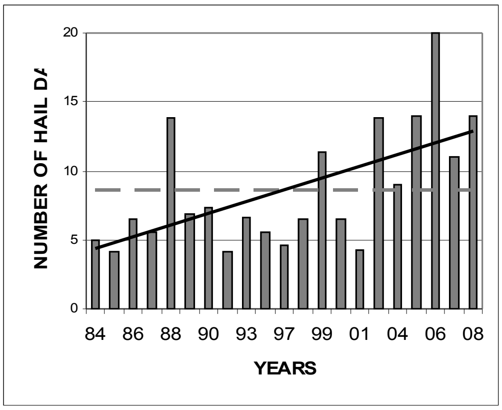

FIG. 2: Yearly distribution and trend of the number of hail days.

The yearly distribution of mean maximum daily diameter of the hailstones shows a decreasing trend. The decreasing trend of the absolute maximum yearly diameter, combined with the slightly increasing trend of the yearly number of hailstones, might imply the effect of seeding. The absolute maximum diameter ever recorded was 34.7 mm. Mean, maximum values and trends are presented in Table 1.

Parameter	Mean	Max	Trend
Number of storms	18	48	Increase
Number of haildays	9	20	Increase
Number of pads hit	51	124	Increase
Number of stones	3440	9525	Slight increase
Maximum hailstone diameter (mm)	23.3	34,7	decrease
Mean maximum daily diameter (mm)	13.9	20,8	decrease

TABLE I. Mean values, maxima and trends of several hail and hailpad parameters.

From the examination of the monthly distribution of the number of hailstorms and of hailpads hit per day, it is concluded that the maximum convective activity occurs in June. From the distribution of the number of stones per pad, per storm and per day, one can state that weaker storms (with a great number of stones, however of small size) occur in April, while the maximum number of hailpads hit per storm occurs in September, when storms are more extended and faster moving (Foris et al., 2006). By examining the monthly distributions of the relative frequency of occurrence of hail days (Figure 3), of hailstorms, of hailpads hit and of the total number of hailstones (all of them having similar distributions), it is concluded that the most frequent and most intense convective activity occurs in June and May, when the atmospheric instability is maximized.

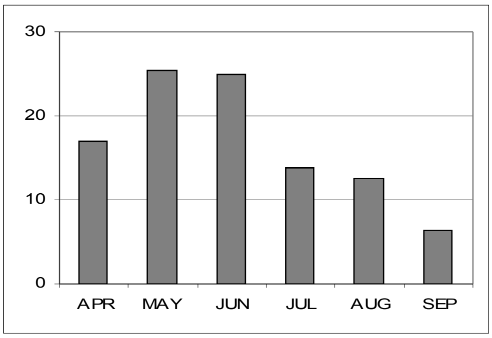

FIG. 3: Relative monthly frequency of hail days.

Since hailpads do not record the time of hailfall, it was decided to record the time of initiation of the hailstorm that produced a certain hailfall. It is reasonable to assume that the time of hailfall occurs 30 to 60 minutes after the time of onset, depending on storm structure and evolution. Its distribution is nearly normal, centred around 15 UTC, which for the warm season coincides with maximum heating, implying that convection plays a key role in storm development, especially for air-mass thunderstorms. Furthermore, it is observed that storms develop also during the early evening hours, in accordance with other findings (Karacostas, 1991). This is partly due to the orientation of certain mountain slopes relative to solar radiation and the duration of this exposure, and partly to cloud destabilization occurring in evening hours owing to radiation emission from cloud tops.

By examining the maximum diameter of hailstones produced by a hailstorm in relation to the storm's maximum reflectivity it is concluded that seeding reduces the maximum diameter of hailstones. This result holds also true for the number of hailstones per storm, and is still verified when the data are stratified in three reflectivity classes, namely Z≤45 dBZ, 45<Z≤55 dBZ and Z>55 dBZ. The effect of seeding is most pronounced in the first two classes, while for the highest reflectivities it is reduced.

In Table 2 the minimum values of radar characteristics producing hailfalls are given in relation to hail size classes. Both maximum reflectivity and maximum top height values are higher in cases of seeding, implying that a certain maximum hailstone diameter can be reached with weaker storms if seeding does not take place.

Hail size	Minimum reflectivity (dBZ)		Minimum top height (km)	
	Seed	No seed	Seed	No seed
Pea	37	35	6	5.5
Grape	43	33	8	7
Walnut	55	50	10.5	7

TABLE II. Minimum radar characteristics for hail size occurrence in cases of seeding and non-seeding.

III. RESULTS AND CONCLUSION

The study of hailpads hit in a 21-year period in the area of Central Macedonia leads to the following results: 1. Hailfalls are more frequent in the north part of the project area, in a close relation to terrain features. 2. Hail activity shows an increasing trend, while the maximum diameter of hailstones a decreasing trend. 3. The most intense convective activity occurs in June and May, in accordance to the existence of increased atmospheric instability. 4. The timing of storms' onset coincides in general with the maximum heating hours of the day. 5. The seeding of storms reduces the maximum diameter and the number of hailstones.

IV. REFERENCES

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