HAIL FREQUENCY AND INTENSITY IN NORTHERN GREECE

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(Dated: May 14, 2007)

I. INTRODUCTION

Hail in northern Greece is common during the warm season of the year, from April to September, and it is frequently associated with considerable damage to agriculture and property. It is classified among the major weather threats, occasionally causing large damage to crops that result in significant economic loss (Kotinis-Zambakas, 1989; Sioutas, 1999; Sioutas and Flocas, 2003).

In this research paper, a comprehensive hail climatology for the region of central Macedonia, northern Greece, is presented. Hailfall characteristics studied include frequency and spatial distribution and parameters such as hailstone size distribution and total kinetic energy. An assessment of northern Greece hailstorm intensity is also undertaken, by examining possible relationship to crop damage and by using the H-intensity scale of the Tornado and Storm Research Organisation (TORRO), as introduced by Webb et al. (1986). All the available hail data were examined, including three main sources: the Hellenic National Meteorological Service (HNMS) conventional meteorological stations data, the Hellenic National Agricultural Insurance Institute (ELGA) crop insurance hail data, and the ELGA hailpad network data.

II. PRESENTATION OF RESEARCH

Climatological hail records, as provided by HNMS conventional stations, are referred to days of hail observed on the ground. These data can describe the "point" frequency of hail that can be representative of an area of about 100 to 1000 m^2. Based on data from about 70 HNMS stations for the whole of Greece over more than 60 years, hail is most common over the western Greece coastal areas, where there is a mean maximum of 8 hail days. HNMS data showed a yearly average of 2 hail days (point events) for the central Macedonia, northern Greece.

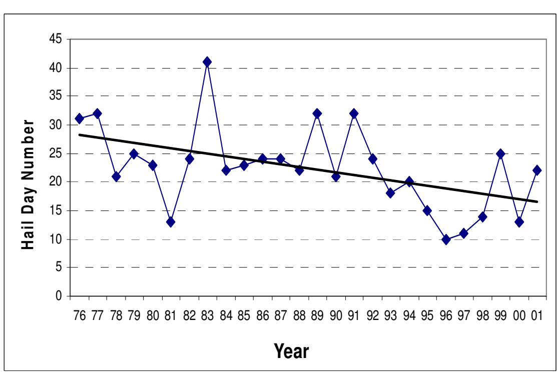

FIG. 1: Frequency and trend of hail days (April-Sept.) in central Macedonia, using insurance data for the 26-year period 1976-01.

The insurance hail loss database of the Hellenic National Agricultural Insurance Institute (ELGA) for central Macedonia, was also examined. A "hail day" based on the ELGA database is defined as a day during which hail was observed that caused damage to the crop of at least one municipal (community). The frequency of hail days during the 26-year period (1976-01) for April to September, demonstrates an average hail-day number of 22.3, for central Macedonia (Fig. 1). Insurance hail data can be considered to determine a "regional" hail frequency, generally applying to an area of about 10^8 to 10^{10} m^2. A maximum of 41 hail days occurred in 1983, while secondary maxima of 32 hail days were recorded in 1976, 1977, 1989 and 1991. A decreasing hail-day trend is prominent during the 6-year period 1993-98 of the most recent decade.

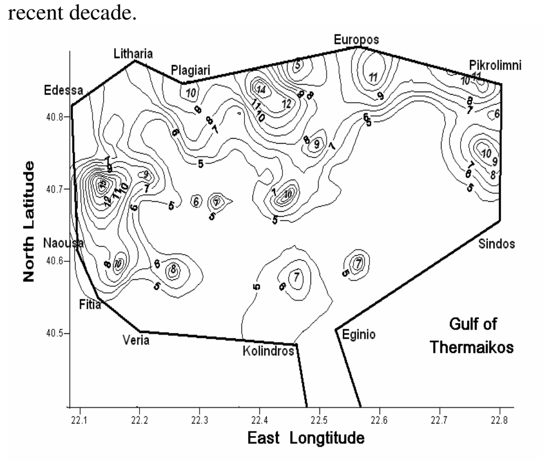

FIG. 2: Total number of hailfalls at each hailpad site location for 17 years of -seasons from April to September, during hailpad network operation (1984-04).

Hailpads have been used in many parts of the world for recording the hail on the ground and sampling of various physical and numerical parameters of hailfalls (Changnon, 1977; Giaiotti et al. 2003; Towery and Morgan, 1977; Long, 1980). In central Macedonia, northern Greece, a hailpad network has been in operation since 1984, under the auspices of ELGA (Sioutas, 1999).

The total hailfall occurrences at each hail-pad site location, for a 17-year period in central Macedonia (1984-04), are plotted in Figure 2 (for hail occurrences above 4). The northern and north-western parts of the hailpad network area exhibit greater values in hail occurrences which are about double those in the southern part. A maximum of 15 "point" hailfalls is located in the north-west, with a secondary maximum of 14 "point" hailfalls in the middle of the northern part of the network area. It should be pointed out that the northern and northwest maxima of hailfalls within the hailpad network are located at higher altitude and closer to mountain barriers, areas typically expected as hail prone regions.

By examining the relationships between hailfall parameters and damage to crops, the total hail kinetic energy integrated during a hailfall event was mostly related to crop damage. Based on the total kinetic energy classification as suggested by Strong and Lozowski (1977), a percentage of 80.5% of the central Macedonia hailfalls can produce nil or small damage to crop. Hailfalls with kinetic energy values from 50 to 450 Jm^{-2} that usually cause up to moderate damage, represent about 18% of northern Greece hailfalls compared to 27.2% hailfalls in Alberta, Canada. The severest hailfall category, including kinetic energy higher than 450 Jm^{-2}, corresponds to about 1.2% of northern Greece hailfalls, small in comparison to 4.3% for Illinois, 4.5% for North Dakota and 5.3% for Alberta (Strong and Lozowksi, 1977).

An assessment of northern Greece hail intensity is also undertaken using the hail intensity scale (H-scale) of the Tornado and Storm Research Organisation (TORRO) that was first developed by Webb et al. (1986). A summary of the TORRO H-scale in revised form (November 2005) is provided in Table 1.

TORRO Hailstorm Intensity Scale				
	Intensity category	***Hail diameter (mm)***	***Hail kinetic energy $J{\cdot}m^{-2}$***	***Typical damage impacts***
H0	Hard Hail	5	0-25	No damage
H1	Potentially Damaging	5-15	>25	Slight damage to plants, crops
H2	„	10-20	>125	Significant damage to fruit, crops,
H3	Severe	20-30	>275	Severe damage to fruit, crops, damage to glass and plastic
H4	„	25-40	>450	Widespread glass damage, vehicle bodywork damage
H5	Destructive	30-50	>650	Glass - wholesale destruction, damage to tiled roofs, significant risk of injuries
H6	„	40-60		Aircraft bodywork dented, brick walls pitted
H7	Very destructive	50-75		Severe roof damage, risk of serious injuries
H8	„	60-90		
H9	Super Hailstorms	75-100		
H10	„	>100		

TABLE I: Summary of TORRO hailstorm intensity scale, (Webb et al., 1986). Minor revision Nov 2005, see http://www.torro.org.uk/TORRO/severeweather/hailscale.php

By using hail kinetic energy values as extracted by the hailpad data and the corresponding intervals applying to various levels of the H-scale, H0, H1, H2, etc., it was found that the majority, consisting of 66.1%, of northern Greece hailfall reach up to level H0 of the intensity scale and 25.4% of hailfalls reach up to H1 intensity level. Concerning higher intensity levels, the H2 level corresponds to 4.2% of the hailfalls, H3 to 2.7%, H4 to 1.2%, and H5 to 0.3% of hailfalls.

III. RESULTS AND CONCLUSIONS

Hail in central Macedonia, based on the Hellenic National Meteorological Service data, exhibits a mean yearly "point" frequency of 2 hail days. By using the insurance (ELGA) hail data, an average of 22.3 hail days is estimated as a "regional" frequency for the warm season (April to September). Based on the hailpad network data, a mean number of 8 hail days is recorded seasonally, corresponding to 45 hailpads on average and 5.7 hailpads recorded hail per hail day.

A large spatial variability of hailfall occurrence is notable in the hailpad network area with a maximum in the northwest and a decreasing frequency towards to the south. A strong correlation of hailfalls with the topographical factor is revealed, since the hail maxima are located close to the lee sides of mountain barriers. In contrast, the south-eastern minima of hail occurrence correspond to low elevation areas close to the sea. Concerning hail-size distribution based on a sample of about 22,000 hailstones measured a percentage of 85.5% of the hailstones were found having sizes up to 11 mm. By classifying to conventional categories the maximum hailstones recorded by hailpads, the majority were found to correspond to a pea size (48%) and grape size (44%).

Analysis of the total hail kinetic energy showed that the vast majority of northern Greece hailfalls may cause up to moderate damage to agriculture, a smaller percentage but comparable to cases of north America hailfalls. The TORRO hail intensity scale was also used to assess northern Greece hailfall intensity and damage potential, by using hail kinetic energy values as derived from the Greek hailpad measurements. Most hailfalls, 66.1% were up to level H0 of the H-intensity scale, while 25.4% reached H1 level and 8.5% H2 intensity and above (the threshold for significant damage).

IV. ACKNOWLEDGMENTS

The authors would like to thank the Hellenic National Meteorological Service (HNMS) and the Hellenic National Agricultural Insurance Organisation (ELGA) for providing the hail data used in this research.

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