

HAIL OCCURRENCE IN GREECE

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I. INTRODUCTION

Hail is classified among the major weather threats, resulting in significant economic losses to agriculture and property. Establishing of hail climatologies is of a great importance, offering both to hail research and to estimation of risk and expected level of damage. Climatological data can also be significant inputs in natural catastrophe modelling, in quantifying the hail risk and the financial loss in the insurance and reinsurance industry.

Studies for hail occurrence in Greece have included analysis of average patterns of hail in spatial and temporal scales (Kotinis-Zampakas, 1989) and investigation of hail insurance records and hailpad data (Sioutas et al., 2009). In this research, a climatological analysis of hail occurrence is presented, based on the weather stations data of the Hellenic National Meteorological Service (HNMS), provided from about 50 stations from all over Greece. The objective of this study is to investigate the hail occurrence for the "climatological reference" 30-year period 1961-1990. The Kriging method was used to grid the irregularly spaced station data and produce hail contour patterns. Influence of latitude, longitude and altitude was examined. Spatial patterns and distribution of hail days was also studied, by the using of Principal Component Analysis (PCA).

II. PRESENTATION OF RESEARCH

Hail is a rare and extremely local and small scale phenomenon. In this context, the conventional weather stations networks are rather insufficient for the observation and representative sampling of hail and hailfall characteristics. Given that many hailfalls in many areas are undocumented by weather stations, the establishment of a comprehensive and complete climatology of hail remain as a challenge. The available climatological bulletins of meteorological stations are referred only to days that hail was observed on the ground. These data are analysed to describe the "point" frequency of hail, which can be representative for an area of about 100 up to 1000 m² (Changnon, 1977; Long, 1980).

Based on the HNMS stations data, hail is occurred with a higher frequency in the western parts of Greece and the Ionian Sea islands. Over those areas a yearly average "point" frequency is ranged from 4 to 5 hail days during the examined period 1961-90 (Fig. 1). A hail day frequency of 1 to 2 days is determined for most parts of the country. Hail days over Greek peninsula generally decrease from west to east and from the mountain and interior to coastal areas. Oppositely, in the Aegean Sea hail days increase from west to east, with a yearly maximum of 3.4 hail days over Samos isl. Similar patterns of hailfall spatial distribution have been determined in previous climatological studies with different data periods (Catsoulis and Karapiperis 1981; Pagonis, 2001; Sioutas, 1999). A generally decreasing of hail occurrence is determined for the 30-year (1961-90)

determined frequencies comparing with those of previous periods, especially for stations of long period of operation (HNMS Climatic Data, 1978). However, a further investigation for a more detail description of hail occurrence is needed, given the sparse stations network operated by the HNMS, not sufficient for an adequate observation and recording of hailfalls. The figure of hail provided by weather stations, should be also completed with additional sources including insurance, hailpad data, and other reliable reports from local services and authorities (Giaiotti et al., 2003).

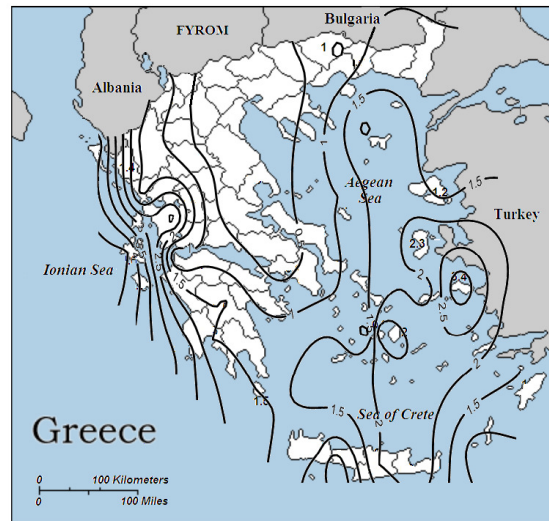


FIG. 1: Annual average number of hail days in Greece, based on conventional weather stations data for the 30-year "climatological reference" period 1961-90.

The HNMS stations data indicated also a large seasonal variability, with most continental parts of Greece affected by hailfall activity mainly during the warm period of the year (April to September), while, coastal and island areas mainly affected during the cold period of the year (October to March). This characteristic is primary attributed to the climatic background of Greece. Based on seasonal hail day frequency, the weather stations were classified as maritime (M) or continental (C), or the transition type (MC), according their maximum of hail occurrence in the warm or cold period. The resulted hail climatic type characterization of each station can be expressed by "h", given by the ratio:

$$h = fw / fc$$

where, fw=hail day frequency for the warm period, and fc=hail day frequency for the cold period. Values of h less than 1 indicate maritime (M) hail climatic station type, while greater than 1 continental (C) hail type. Values close to 1 indicate stronger continental influence and these stations are classified as of transition hail type (MC). In Table 1, the warm and cold period hail frequencies are given along with

the hail climatic types for some Greek weather stations. The majority of the stations are classified to maritime (M) hail type, including most coastal and southern Greece stations. In the continental type (C) classified most inland and higher altitude stations as well also stations of northern Greece.

Weather station	Warm period (April-Sept.)	Cold period (Oct.-March)	Climatic Type
Alexandroupolis	0.14	1.07	M
Serres	0.34	0.09	C
Macedonia airport	0.22	0.06	C
Kastoria	1.00	0.30	C
Trikala, Thessaly	0.37	0.17	C
Ioannina	0.64	0.60	MC
Corfu	0.76	3.51	M
Kefalonia	0.60	3.97	M
Kalamata	0.20	1.30	M
Helliniko, Athens	0.03	0.50	M
Samos isl.	0.23	3.21	M
Iraklion, Crete	0.16	1.85	M
Rhodes isl.	0.07	1.36	M

TABLE I: Mean number of hail days for Greek regions, for the warm (April-Sept.) and cold period (Oct.-March) and station hail climatic type classification (1961-90).

In Figures 2 and 3, the spatial distribution of hail day frequency is given, for the warm and the cold period, respectively. During the warm period, the highest “point” frequency of hail is appeared over the central western and northern Greece (Agrinio-1.2 hail days, Kastoria-1 hail day, Drama-0.85 hail days). This pattern however, is biased because of the sparse network of weather stations and the resulted observation gaps and spatial differences in hail documentation. By using of the agricultural insurance data, for the farmland of central Macedonia, northern Greece, the seasonal (Apr.-Sept.) hail day “regional” frequency was estimated at 22 hail days (Sioutas and Flocas, 2003).

In the cold period, maxima of hail are located over western Greece, the eastern Aegean Sea and Crete. A cold season hail day number of 3.51 is determined for Corfu Isl. and 3.97 for Kefallonia Isl., in the Ionian Sea.

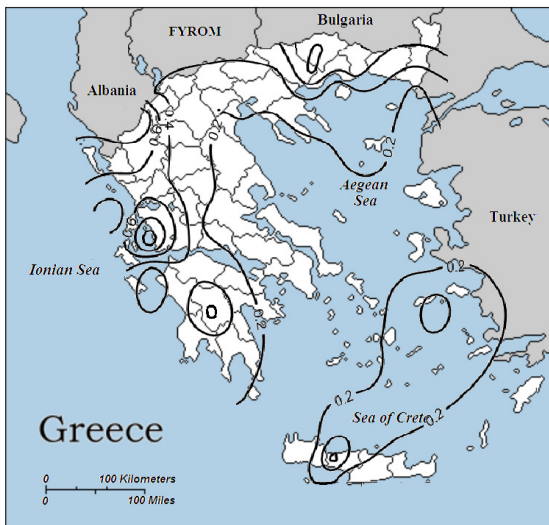


FIG. 2: Average number of hail days for the warm period of the year (April-September), based on weather stations data for the 30-year “climatological reference” period 1961-90.

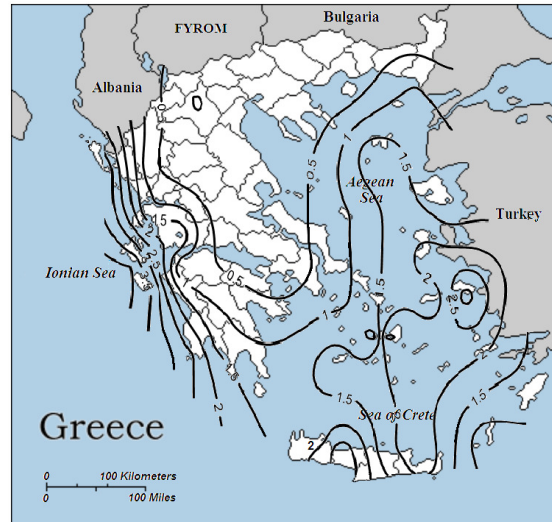


FIG. 3: Average number of hail days for the cold period of the year (October-March), based on weather stations data for the 30-year “climatological reference” period 1961-90.

Average monthly distributions of hail days for selected meteorological stations are showed in Figure 4.

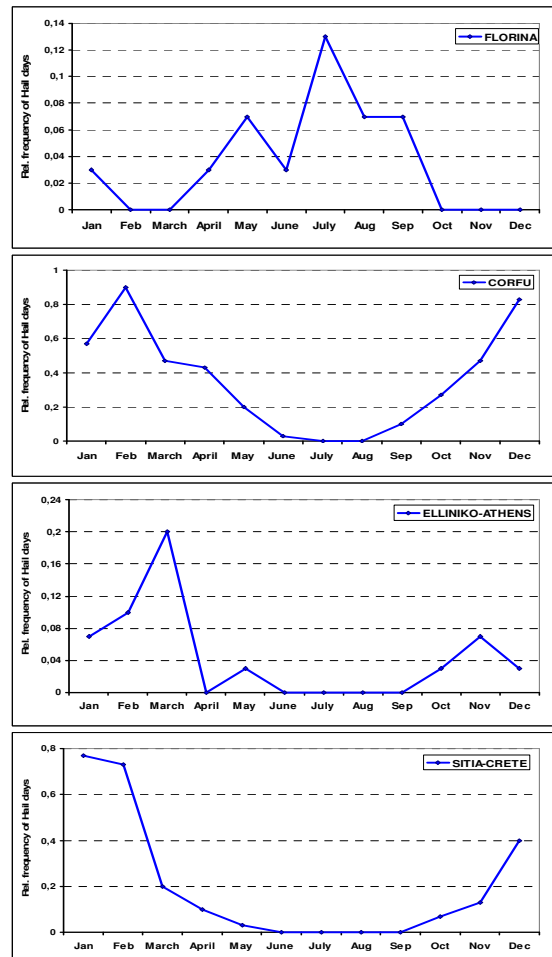


FIG. 4: Monthly frequency of hail days for selected weather stations of Greece for the 30-year period 1961-90.

Overall, spring and summer are the prime hail seasons for C hail type stations with May and June the highest hail frequency months, while January and February are the prime hail frequency months for M type of stations.

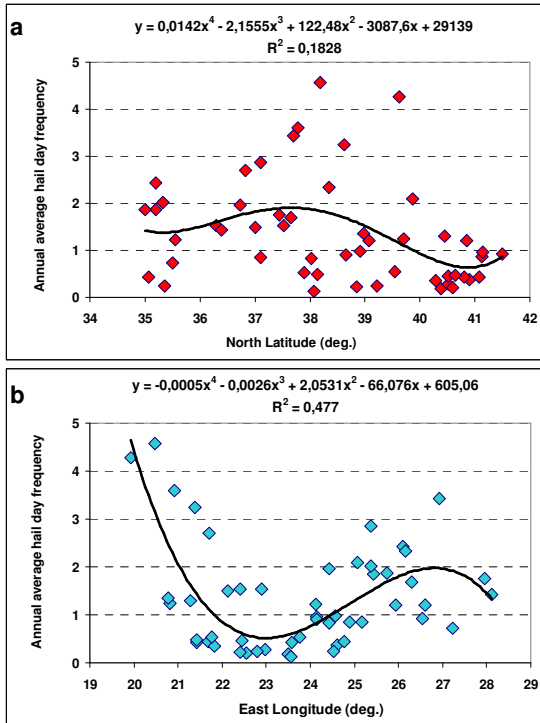


FIG. 5: Annual average frequency of hail days in Greece, as a function of: a) station latitude and b) station longitude, for the 30-year data 1961-90.

Figure 5a represents the relationship with latitude of the average annual hail day number. An increasing of hail occurrence is evident between 37.5° and 39.5° north latitude. The 4th degree polynomial model explains a percentage of 18,3% of the total variance. The relationship of hail occurrence with longitude is displayed in Figure 5b with the polynomial model expressing the 47,7% of the total variance. A decreasing of hail occurrence is evident from western to the interior and eastern parts of Greece (20° to 23° east longitude zone), with increasing hail frequency again in the Aegean Sea (after 23° east longitude) towards the coasts of Turkey.

The effect of altitude up to 500 m did not appear having any significant contribution on hail frequency and rather the only effect appears to be that of climate as it is expressed by the station hail climatic type. A principal component analysis (PCA) was also performed on monthly hail frequency distributions for the 30-year period data (1961-90). The first component (PC1) includes stations of north-western Greece, the Ionian Islands, the Eastern Aegean and Crete Isl., and the second (PC2) stations mainly of north-central Greece.

III. RESULTS AND CONCLUSIONS

Hail occurrence in Greece exhibits a considerable spatial and temporal variability. Based on the National Meteorological Service (HNMS) weather station data for the “climatological reference” 30-year period 1961-90, the yearly maximum “point” frequency averaging 4 to 5 hail

days is located in the centre-western Greece. A yearly average of 1 to 2 hail days is determined for most parts of Greece. Western Greece exhibits the highest hail day number, with a decrease towards eastern Greece. After a decreasing until about 23° east longitude, the eastern lowland parts of Greek peninsula, the hail frequency is increasing again in the Aegean Sea towards the coasts of Turkey. The relationship of hail occurrence with latitude examined over Greece, showing an increasing of hail between 37.5° and 39.5° north latitude zone.

Greek weather stations were classified in hail climatic station types, as maritime (M) or continental (C), or the transition type (MC), according their maximum of hail occurrence in the warm or cold period. The majority, including most coastal and southern Greece stations, are classified to maritime (M) hail type. May and June are the highest hail frequency months for C type of stations, while January and February are the prime hail frequency months for M station types.

A seasonality of hail is revealed, with the highest frequency of hail days occurring in the central western and northern Greece during the warm period of the year (April to September). In the cold period (October to March), hail day maxima are noted along the western Greece, the eastern Aegean Sea and Crete Island. Principal component analysis (PCA) on hail frequency distributions revealed further hail spatial features by grouping weather stations of various districts of Greece.

IV. ACKNOWLEDGMENTS

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