Radiosonde observations of storm environments in Northern Greece

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Introduction

In Northern Greece, hailstorms are common during the warm season of the year, producing significant damage to crops of the agricultural plain of the Imathia and Pella Prefectures.

OBJECTIVES of the study:

Examination of radiosonde observations as proximity soundings in order to:

1. Examine monthly distributions of convection-related parameters for hail events
2. Document the environments for hail and non hail storms over Northern Greece
3. Compare the environments of severe and non severe hailstorms considering thermodynamic and kinematic parameters

Some definitions

Hailpad directly extracted parameters: minimum and maximum diameter of each dent & number of dents per hailpad.

Hailpad indirectly extracted parameters: maximum diameter of each hailstone (digital analysis with Image-Pro®Plus Version 5.1)

Classification of each hailstone of the pad into 3 size classes:

- **pea (0.5–1.2 cm)**
- **grape (1.2–2.0 cm)**
- **walnut (2.0–3.2 cm)**

The largest hailstone that hit the hailpad determines the classification of the hailpad in 3 categories: pea-size, grape-size or walnut-size hailpad.

A hail day is classified into the pea-size, grape-size or walnut-size hail day according to the hailpad with the largest classification category on that day.

Only storms that occurred within the protection and the verification area of the GNHSP in Northern Greece are considered in the study.

Study area

In the agricultural plain of Central Macedonia, in Northern Greece, an airborne seeding program for hail suppression has been operating since 1984 by the Hellenic National Agricultural Insurance Organization (ELGA), with the aim of minimizing crop losses. The Greek National Hail Suppression Program (GNHSP) runs between 20 March and 30 September every year. A hailpad network, currently consisting of 157 hailpads, is also operating over the area recording several hail parameters extracted directly or indirectly (Fig. 1).

Hailpad: a square piece (29×29 cm) of styrofoam material (Ravatherm XPS) and 25 mm thick, mounted in an aluminium bracket on the top of a post about 1.5 m above the ground.

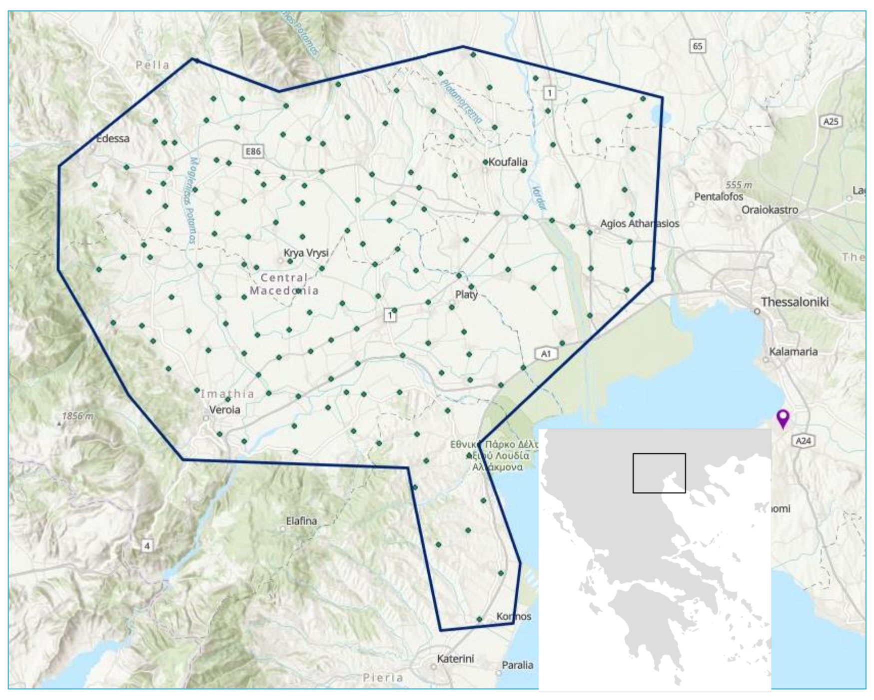


Figure 1. Protection and hailpad network area of the GNHSP in Northern Greece and location of radiosonde station (purple pinpoint).

Methodology I – dataset classification

Dataset

A total number of **269 days for the period 2020-2024** was taken into account and these days were divided into 2 categories:

a. **Days with hail on the ground-HAIL DAYs:** at least one hailpad with hail dents is recorded or hail damage report was filed at ELGA regional branches (175 days)

b. **Days with limited convective activity-NO HAIL DAYs:** limited and shallow convective activity without lightning (identified through radar measurements from a C-band-5 cm weather radar located at Filyro Mountain near Thessaloniki) (94 days)

Out of the 175 hail days, 90 days correspond to recorded hail on hailpads and 85 to days that hail on ground was verified through damage reports (without reported hail size).

The 90 days were divided into two intensity categories:

a. Days with **hail size ≤ 1.2 cm** (**non-severe**) – 42 events

b. Days with **hail size > 1.2cm** (**severe**) – 48 events

Monthly distribution (hail days)

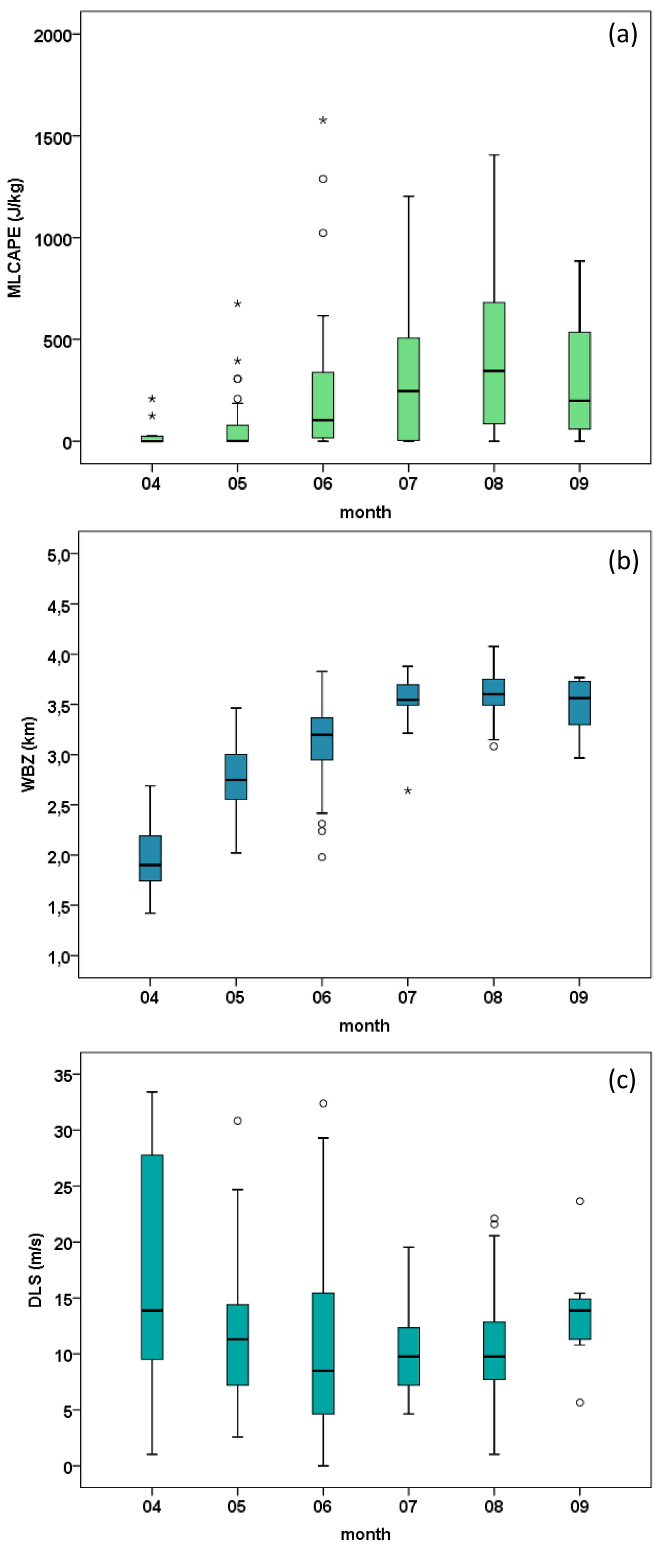


Figure 2. Monthly distributions of MLCAPE, WBZ and DLS. Period 2020-2024.

MLCAPE: median values increase from spring to summer and lower in September. There is overlap of values between July and September with highest values recorded in August (Fig. 2a).

WBZ height: median values clearly increase from spring to summer. In July and August WBZ is mostly higher than 3.5 km. The interquartile range between July and September is narrower than in the rest of the season (Fig. 2b).

DLS (0-6km): high range of values. Median values remain lower than 15 m/s. They lower from April to June, while increase between July and September (Fig. 2c).

Methodology II - proximity soundings

Radiosonde measurements are carried out daily at 0600 UTC during the GNHSP taken at the Regional Meteorological Center of Macedonia located within Thessaloniki's Airport (purple dot on map of Fig. 1). Their range covers a radius of 150 km that satisfies the criterion for proximity to storms that are formed within the Protection Area of the Project. From these data a number of convection-related parameters are calculated using SHARPpy software (Table 1).

Table 1. Convection-related parameters used in the study.

Parameters description	Abbreviation	Units
100-hPa mixed-layer CAPE	MLCAPE	J/kg
Avg temperature lapse rate between 700 and 500 hPa	LR 700-500	°C/km
Avg temperature lapse rate between surface and 3km	LR 0-3km	°C/km
Mid-level Relative Humidity (850-650 hPa at sea level)	MID RH	%
Low-level Relative Humidity (roughly surface-850 hPa at sea level)	LOW RH	%
Lowest 100 hPa mean mixing ratio	mix ratio	g/kg
Wet Bulb Zero	WBZ	km
Lifted Condensation Level using 100 hPa mixed layer parcel	MLLCL	m
Bulk wind shear 0-6km AGL	DLS	m/s
Significant Severe Parameter	SigSev	m^3/s^3

Results - Hail versus non-hail environments

MLCAPE: it distinguishes well between the two categories. Despite the outliers and the extreme values, the distribution of non-hail values is confined to the range between 0 and 100 J/kg, while for the hail cases the spread reaches 900 J/kg (Fig. 3a).

Lowest 100 hPa mean mixing ratio: hail cases exhibit higher median values than non hail ones. Hail storms form with higher amount of humidity in the atmosphere (Fig. 3b).

MLLCL: does no distinguish well between the two environments.

LR 0-3km: overlap between the two distributions, but in general lower values for non hail environments.

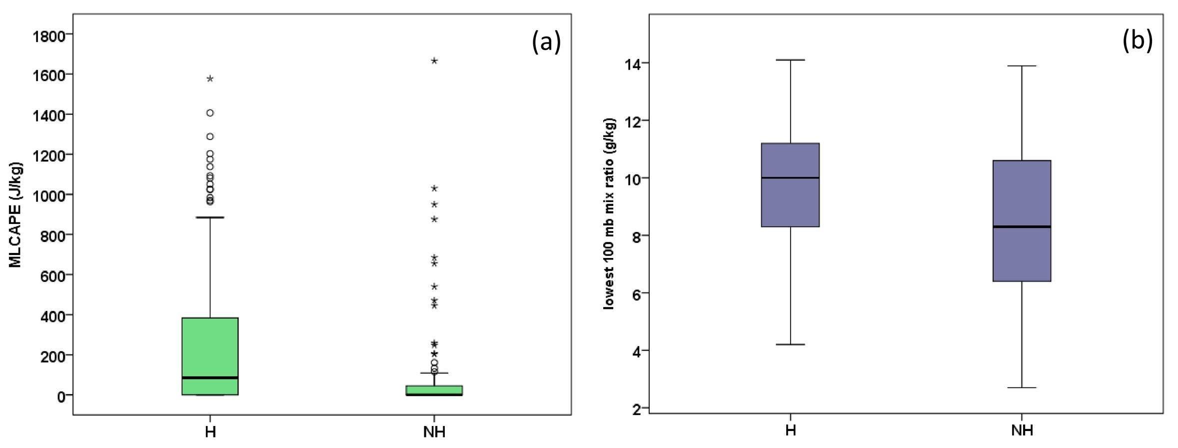


Figure 3. Box and whisker plots of MLCAPE and lowest 100 hPa mean mixing ratio. 10th, 25th, 50th, 75th and 90th are shown, as well as outliers (open circles) and extreme values (asterisks) for hail and non hail days of the period 2020-2024.

Results – severe vs non-severe events

MLCAPE increases with increasing intensity. Except some exceptions (outliers) non-severe events have MLCAPE less than 600 J/kg. Severe events exhibit high interquartile range (Fig. 4a).

LR 0-3km Medians near 6.5 °C/km for non-severe cases and 6 °C/km for severe ones (Fig. 4b).

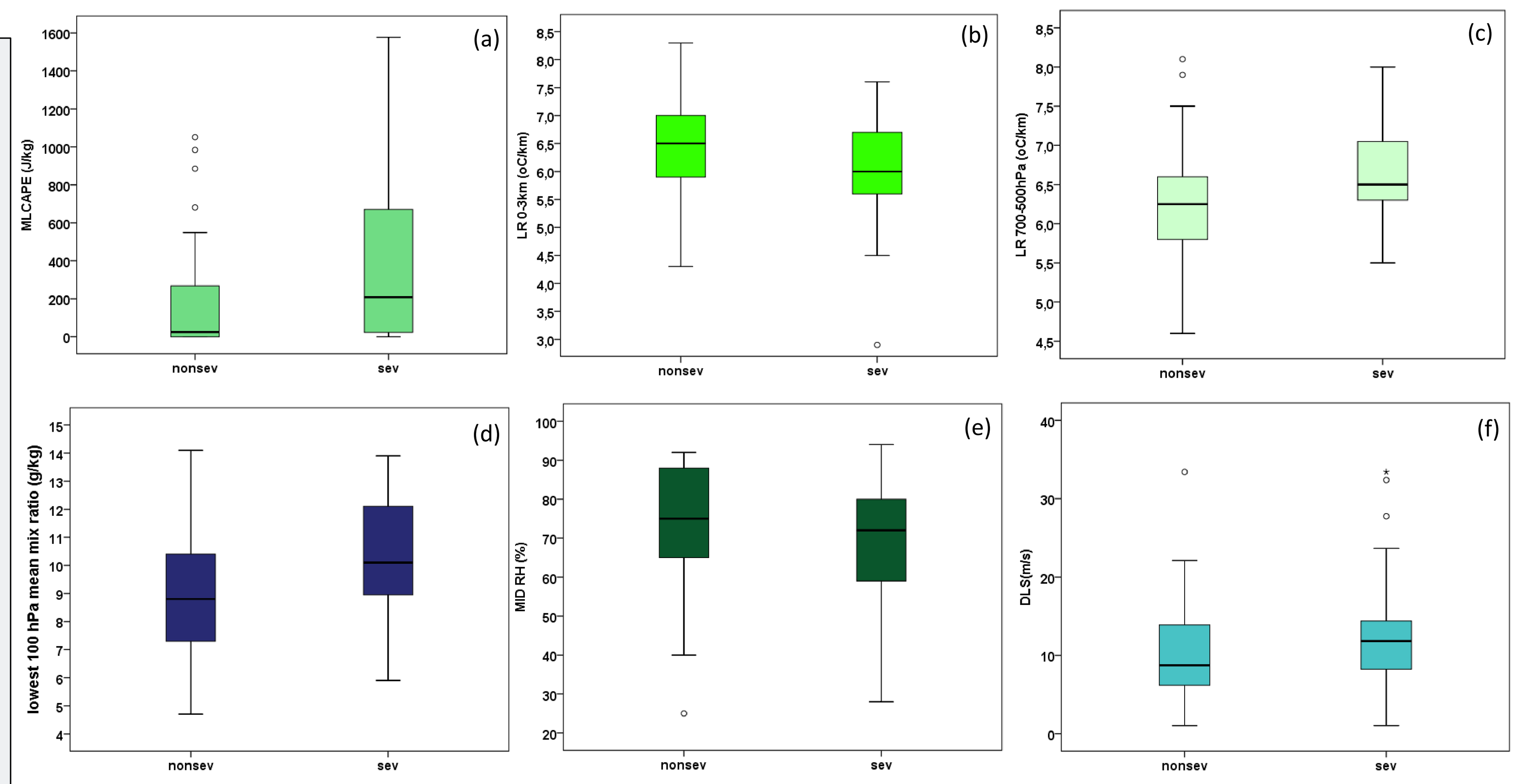
LR 700-500 severe weather episodes tend to have steeper values. 75% of the severe events have lapse rates over 6.3 °C/km. High interquartile range of the parameter for non-severe events (Fig. 4c).

Lowest 100 hPa mean mixing ratio Overlap between the distributions, but severe cases exhibit higher values than non-severe cases (Fig. 4d).

MID RH Overlap between the two categories, but severe cases tend to have lower values than non-severe ones. 75% of the severe events have values lower than 80% (Fig. 4e).

DLS Similar interquartile range between the two classes, but increase of the values with increasing intensity (Fig. 4f).

SIGSEV Most of the non-severe cases have values lower than 4000 m^3/s^3, the median for severe cases. Severe cases reach values of 15000 m^3/s^3 (Fig. 4g).



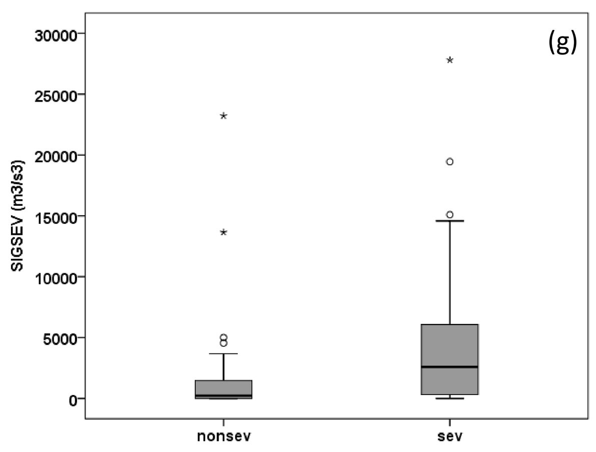


Figure 4. As in Figure 3 but for MLCAPE, LR 0-3km, LR700-500 hPa, lowest 100 hPa mean mixing ratio, MIDRH, DLS and SIGSEV for non-severe and severe events of the period 2020-2024.

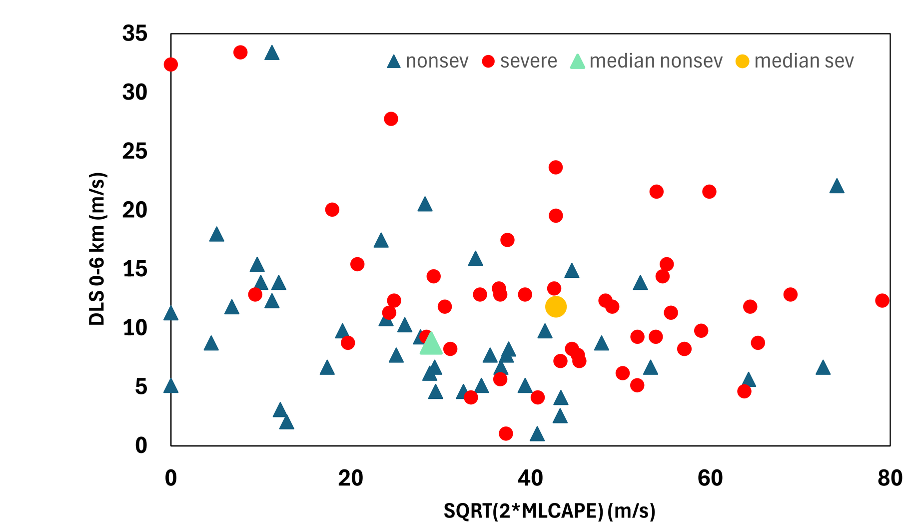


Figure 5. Scatterplot of non-severe (blue triangles) and severe hail events (red dots) with respect to the distribution of $(2xMLCAPE)^{1/2}$ and DLS. The large green triangle and the orange dot represent the median values of the two parameters.

Non-severe and severe events (Fig. 5) occur for a range of the 2 parameters values. Increase of both MLCAPE and DLS leads to increase in severity. For the severe events the highest concentration is limited to high MLCAPE and high DLS. Median values of the two are higher for severe, than for non-severe events.

Discussion

- Environments of hail events exhibit higher MLCAPE, mixing ratio and 0-3km lapse rates, than non-hail events.
- Seasonal variation of the parameters show that MLCAPE and WBZ increase from spring to summer, but for the rest of the parameters no clear outcome can be reached.
- Large hail typically occurs with high CAPE and its probability increases with higher shear. Radar data show that these severe hail events are multicell or supercell storms.
- Severe hail is associated with lower cloud bases (MLLCL), lower 0-3 km lapse rates and higher mixing ratio. This is an indication that moist boundary layer reduces the degree of mixing and this results to a shallower layer and lower cloud bases.