Radar Derived Storm Characteristics Over Central Greece

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Abstract Individual storm measurements are obtained from the C-band weather radar, located close to the area of interest, using the cell tracker TITAN (thunderstorm identification, tracking, analysis, and nowcasting). The study aims in analyzing certain storm characteristics over central Greece, as a tool for investigating possible rain enhancement feasibility potential. The objective on this study is two folded: firstly, to analyze and describe storm characteristics and secondly, to identify differences in storm characteristics, structure and their behavior, among distinct synoptic situation patterns. The radar-based storm characteristics are extracted using certain thresholds. Storm characteristics include: storm initiation time, storm duration, storm motion, cloud top, reflectivity, storm volume and storm area. Frequency analyses of the aforementioned findings bring out evidences of the storm characteristics, their extends and limitations, providing thus an integrated view of the experienced isolated storms over the examined area. Moreover, the classification of the storm days reveals certain differences in several storm properties, indicating how isolated storms over central Greece vary under different synoptic situation patterns.

1 Introduction

Convective storms are meteorological phenomena of great importance as they are associated with extreme events, while at the same time are not captured accurately by any conventional observation system, since they exhibit small-scale characteristics, lifetime and size. The purpose on this study is to analyze and describe radar-based storm characteristics and to identify differences in

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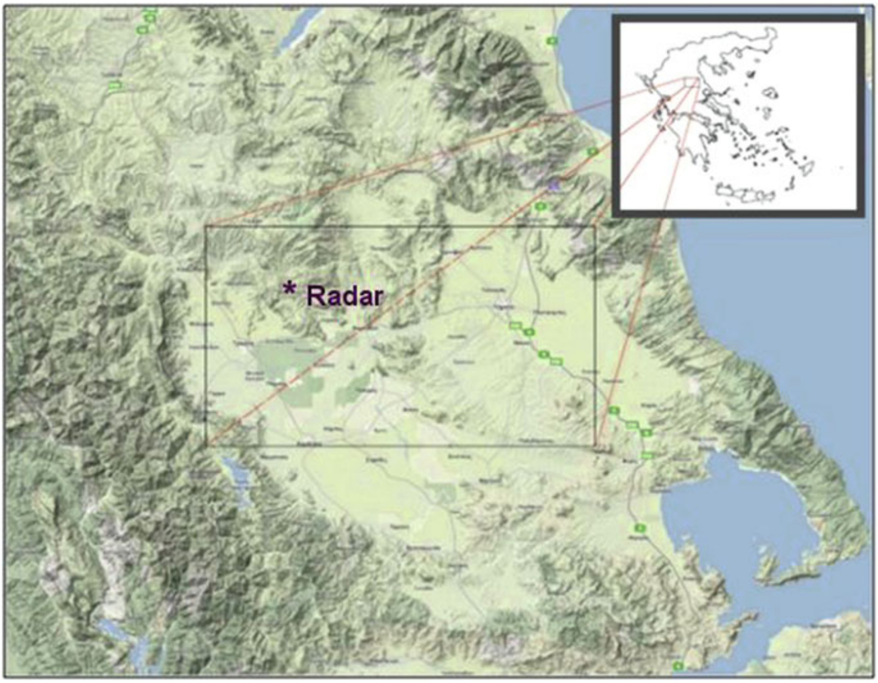

Fig. 1 The study area over Thessaly, Greece

storm characteristics among distinct synoptic situation patterns over central Greece.

Radar data-based storm characteristics studies appeared in the USA in the 1950s following the invention and first use of weather radars (Braham 1958). In Greece, radar-based storm studies have been performed by Karacostas (1991), who investigated convective cells characteristics after the first 2 years (1984 and 1985) of operations of the Greek National Hail Suppression Program (NHSP), Sioutas and Flocas (2003) who analyzed the hailstorm characteristics in northern Greece through synoptic typing and thermodynamic environment and Foris et al. (2006) who performed a kinematic study of hailstorms in central Macedonia.

Storm characteristics are obtained and identified from weather radar reflectivity images taken and analyzed from a C-band (5-cm) weather radar, being located at Liopraso area, within the area of interest. Such information is considered as diagnostic, since it can assist – as a very useful tool – for investigating rain enhancement potential over the area. The area selected for the analysis covers 4,000 km^2 (rectangular 50 $\times$ 80 km) and is mostly plain, within the eastern part of Thessaly (Fig. 1). Only storm cells that initiated (gave their first radar echo) within the area of interest are used in this analysis.

2 Data and Methodology

The dataset that is used in the analysis includes radar reflectivity measurements for the time period of April 2006 to September 2010, focusing only on the month period April to September, for each year. The radar reflectivity measurements have 750 × 750 m spatial and 3.5 min temporal, resolution. Storm characteristics are obtained from reflectivity measurements using the cell tracker TITAN (Thunderstorm Identification, Tracking, Analysis, and Nowcasting) (Dixon and Wiener 1993). Storm characteristics include: storm initiation time (UTC hour), storm duration (minutes), storm direction (°), storm speed (km/h), storm volume (km^3), storm mass (ktons), storm maximum reflectivity (dBz) and storm cloud top (km).

The cell tracker TITAN is developed for automatic identification, tracking and forecasting of convective cells. The algorithm, at a given reflectivity image, defines a convective cell as a 3D region in which reflectivity values exceed a given threshold and match convective storms between two successive radar images. To be considered a valid storm, a track must satisfy a set of criteria and threshold values, regarding its own characteristics. Hence, the following have been set for the current analysis:

1. A storm track is rejected if it begins or ends after or before a missing radar file.
2. A storm track is discarded if its top is missing, since it lies too close to the radar (within the cone of silence).
3. The storm minimum volume must be at least 15 km^3.
4. A storm track must have a minimum duration of 15 min (five successive radar scans).
5. The storm volume area reflectivity must exceed 35 dBz.
6. A storm track must have maximum top above 3.5 km.

For criterion 5 the 35 dBz was chosen, since that value is the threshold for the storms to be seeded during the NHSP (Karacostas 1984) and it correlates well with the development of mature cumulonimbus clouds (Roberts and Rutledge 2003). With respect to criterion 6, a cloud with maximum top below 3.5 km is discarded, since it is likely not to be a convective storm.

3 Results

3.1 Storm Characteristics

Following the above procedure and selection criteria, a total number of 514 valid storm cells are identified by the algorithm. The percent relative frequency of the storm characteristics is depicted in Fig. 2.

As seen in Fig. 2, convective cells that affect the area of interest develop during the afternoon hours, with a peak at 14:00 UTC indicating that surface heating is the

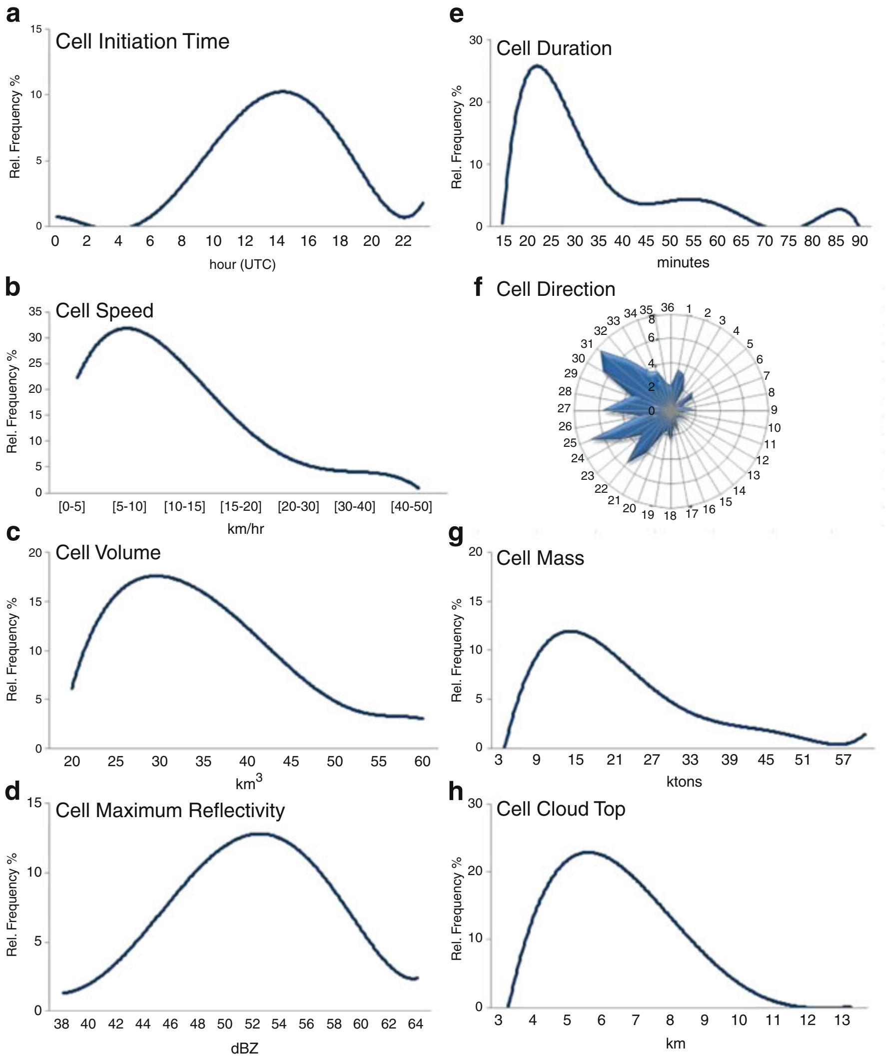

Fig. 2 The percent relative distribution of the observed convective cell characteristics

dominant factor for storm initiation. The identified secondary maximum in storm initiation time at 00:00 UTC is most probably due to cells that have developed during the previous day and continue to exist after midnight. Cells exhibit a lifetime up to 40 min in a percentage of 72%, with a peak at 25 min, indicating that cells that affect the area are short lived. It is noted that lifetime is defined as the time elapsed from the first radar echo of 35 dBz until the disappearance of that.

Cell motion peak speed is between 6 and 10 km/h and cell direction of movement is from northwest and southwest, which is mostly related to the 500 hPa upper

Table 1 Number of cells per synoptic circulation type

	Number of cells	Number of cells with duration 15–35 min
Southwest flow (SW)	61	34
Short wave trough and closed low (L2-CLO)	157	93
Northwest flow (NW)	135	84
Cut off low (CUT)	17	13

air winds. Regarding cell's volume and mass it is found that cell volume ranges between 20 and 45 km^3 in a percentage of 64% and cell mass between 6 and 21 ktons in a percentage of 55%. Finally, cell's reflectivity peaks at 54 dBz with 73% of cells ranging between 46 and 58 dBz and cell cloud top most frequently encountered at 7 km, with 55% of cells having cloud tops between 6 and 8 km.

3.2 Storm Characteristic Differences Among Synoptic Types

In order to study the connection of atmospheric circulation with convective activity over the examined area the manual classification scheme proposed by Karacostas et al. (1992) is used, which is based on the isobaric charts of 500 hPa and the position and orientation of the trough axis. Furthermore, circulation patterns that produced storms over the examined area, are grouped into the following four types: (1) southwest flow (SW), a long wave trough to the west of the examined area, (2) short wave trough and closed low (L2-CLO), referring mostly on storms produced during the developing stage of a surface low pressure system, (3) northwest flow (NW), along wave trough located to the east of the area, and (4) cut off low (CUT), referring on storms developing during the mature phase and dissipating stage of an upper air and surface low system.

The number of cells grouped under the four types is indicated in Table 1. In order to study cells of similar duration, a second grouping is performed only for cells that exhibit lifetime between 15 and 35 min. Cut off low (CUT) cases are excluded from the results due to their small sample size.

It can be seen that most cases of cell development refer to two different synoptic types, the short wave trough – closed low (L2-CLO) and the northwest flow (NW). Results indicate the following: cell characteristics between these two synoptic types differ in initiation time; later peak in relative frequency for cells developing at NW synoptic type, and cell direction; NW type cells follow the northwest to southeast direction, while L2-CLO type cells do not have a clear direction (Fig. 3a, b). Although the rest of cell characteristics (volume, max reflectivity and cloud top) do not show remarkable differences, from the diagrams (Fig. 3c, e, f) it is observed that cells developing at L2-CLO synoptic type exhibit two maximum peaks; almost at the same level; while cells developing at NW synoptic type have only one maximum. This fact indicates a more scattered behavior of cells that develop at

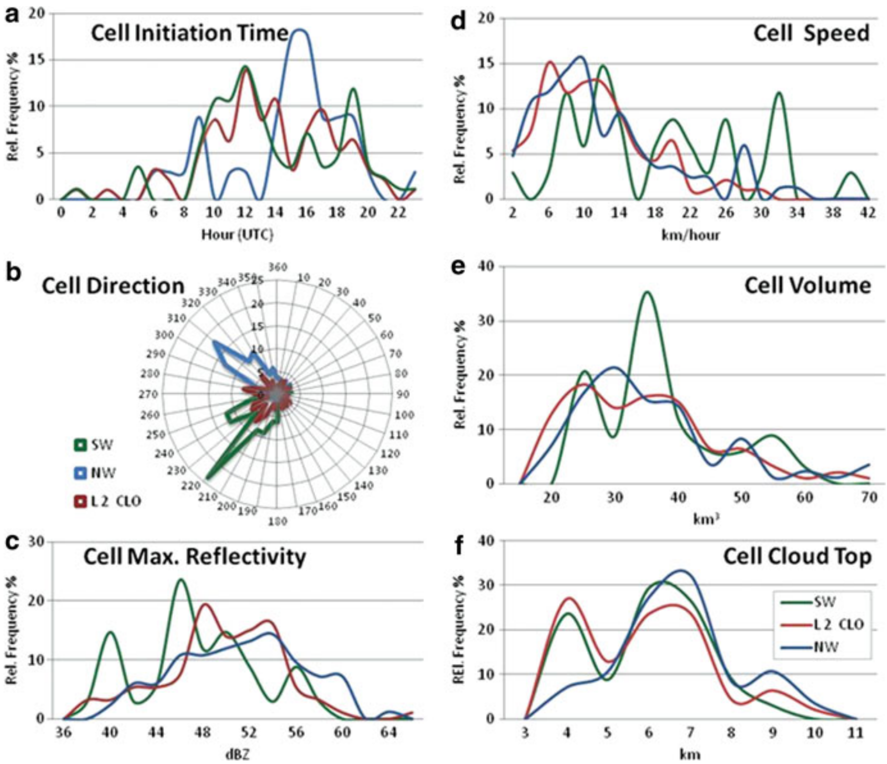

Fig. 3 The relative frequency distribution of the observed cell characteristics per synoptic type

L2-CLO synoptic type, with air masses coming from various directions and having different properties, than those developed at NW synoptic type, where air mass potential is probably restricted. Concerning the cells develop at southwest (SW) synoptic type, they move quite faster, from southwest to northeast, exhibit lower maximum reflectivity values and higher volume and mass content.

4 Conclusions

An attempt is made to analyze and describe storm characteristics, obtained from weather radar measurements for a specific plain area in eastern Thessaly. Frequency distribution of cell characteristics indicated their extends and limitations, providing an integrated view of storms' behavior over the examined area. It appears that convective cells occur mostly in the afternoon. Cells are mostly short lived, with a mean peak at 20–25 min. Cell motion is consistent with upper air winds at 500 hPa. Cell characteristics, such as: volume, mass, max reflectivity and cloud top, follow almost a normal distribution. Furthermore, the storm characteristics are examined in relation to the synoptic types. Certain differences are observed between L2-CLO and NW synoptic types, with cells developing at L2-CLO synoptic type to exhibit more scattered characteristics.

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