A Comparison of Storm Characteristic Between Mountainous and Plain Areas within Central Macedonia

K. Tymbanidis, D. Bampzelis, T. Karacostas, and E. Chatzi

Abstract A comparison of storm characteristics between two selected areas (one mountainous and one plain) of Imathia-Pella region is performed, using radar-derived data taken from the C-band weather radar situated at Fyliro area, close to Thessaloniki and the cell tracker TITAN (Thunderstorm Identification, Tracking, Analysis, and Nowcasting – NCAR). The objective on this study is: firstly, to analyze, describe and compare storm characteristics between the two examined areas, and secondly, to identify monthly differences among them. The TITAN algorithm is used to obtain storm measurements during the months April to September for the 3-year period of 2008–2010. The radar-based storm information is compiled using certain storm-tracking thresholds. Following this approach, the total storm days and cell number, were identified. Results indicate that convective cells that affect both areas differ in number as well as in their characteristics. Cells develop over the mountainous area earlier within the day, move slower, have higher maximum reflectivity values and 35% of them do not precipitate at all. Monthly distribution of relative frequencies also revealed certain differences among transitional and summer months.

1 Introduction

Convective storms are significant meteorological phenomena of great importance, since, despite their local-scale characteristics, are associated with extreme events like heavy rainfall, hail, gusty winds that can cause considerable damage to

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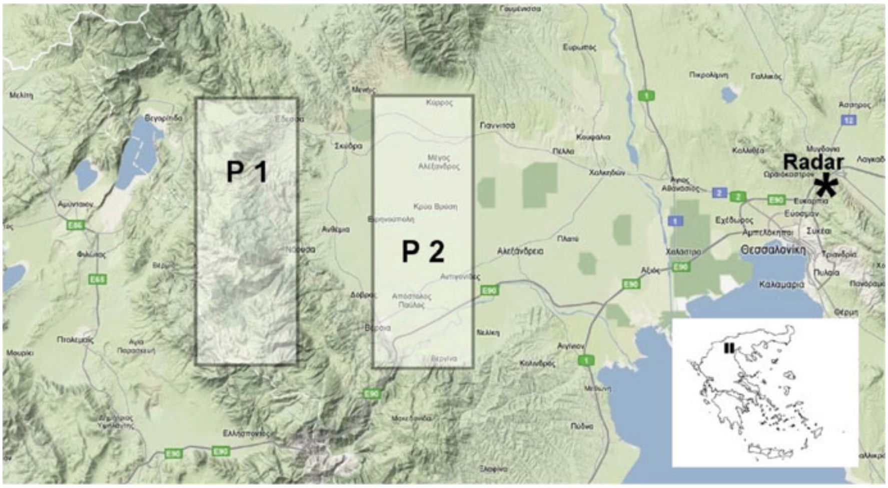

Fig. 1 The P1 and P2 areas of study in northern Greece

agriculture and infrastructure facilities. The purpose on this study is the analysis of radar data, digitally recorded during the Greek National Hail Suppression Program (NHSP) and the comparison of convective cell characteristics between two selected regions (one mountainous and one plain) in Imathia-Pella region. Concurrently, the analysis seeks to identify and compare mechanisms that affect their creation, movement and severity between the two selected areas.

Radar-based storm studies have been conducted by several researchers over the area of northern Greece, such as: Karacostas (1991), Sioutas and Flocas (2003) and Foris et al. (2006). They generally studied convective cell characteristics, and hailstorm characteristics, through synoptic situations, dynamic and thermodynamic environment.

Two areas were defined and are used (Fig. 1) in this analysis and comparisons of the storm characteristics between them is performed. The area P1 is a mountainous area which covers 150 km^2 (mean altitude 927 m), mainly over the mountainous range of Vermion, being to the west, and the plain and agricultural area of P2, which also covers 150 km^2 of Imathia-Pella region (mean altitude 51 m).

2 Data and Methodology

The dataset used for this radar analysis and comparison of storm characteristics between the two selected areas comes from a C-band weather radar situated at Fyliro mountain, close to Thessaloniki, with 750 m $\times$ 750 m spatial and 3.5 min temporal resolution during the April to September months of 2008–2010. The cell tracker TITAN (Thunderstorm Identification, Tracking, Analysis, and Nowcasting – NCAR), (Dixon and Wiener 1993) is used to identify storm tracks and extract storm characteristics. The cell tracker TITAN is developed for automatic identification, tracking and forecasting of convective cells based on radar reflectivity measurements. The algorithm, at a given reflectivity image, defines a convective cell as a 3D region in which reflectivity values exceed a given threshold. Following that, the algorithm matches convective storms between two successive radar images using combinational optimization. The algorithm can also deal with cells that merge or split, classifying them as complex (multicells) or simple (singlecells). The storm characteristics include the following: cell lifetime or duration (mins), hour of start (in UTC time), cell speed (km/h), direction of motion (°), mean cell volume (km^3), mean cell mass (ktons), mean cell area (km^2), mean cell precipitating area (km^2), mean maximum cell reflectivity (dBz), maximum cloud top (km) and maximum height of 35 dBz echo (km).

A number of threshold values are set during the identification procedure by the algorithm, in order to capture only valid convective storms and to eliminate several non-meteorological echoes (i.e. ground clatter). These thresholds include the following: (1) a storm track is rejected if it begins or ends after or before a missing radar file, (2) the storm's minimum volume must be at least 15 km^3, (3) a storm track with a minimum duration less than 15 min (five successive radar scans), (4) a maximum duration of more than 2.5 h and maximum top below 3.5 km is discarded, since it is likely not to be a convective storm, and (5) the storm volume area reflectivity must exceed 35 dBz.

It must be stated that only cells developed within each one of the defined areas (P1 or P2) (give their first echo above 35 dBz) are considered in the analysis. Storms that might have developed elsewhere and passed through one or both areas, are not included in the analysis.

3 Results

With the application of all criteria and threshold values, a total number of 106 storm days with 289 valid cells are defined for area P1 (mountainous area) and 77 storm days with 141 valid cells for area P2 (plain area). It is obvious that mountainous area experiences more storm days and far more cells than the plain one. From the monthly distribution of the number of storm days (Fig. 2, left) and the number of cells developed per storm day (Fig. 2, right) is observed that this difference is mainly due to summer months. The number of cells per storm day for both areas exhibit similar behavior, except for July and August.

3.1 Comparison of Cell Characteristics Between the Two Areas

For the comparison between the two areas, relative frequency distributions were calculated for each cell characteristic and for each area. The comparison diagrams are presented in Fig. 3. The results reveal certain differences in some cell

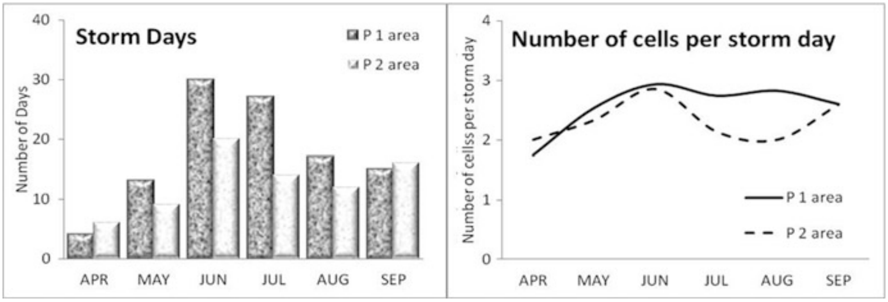

Fig. 2 Monthly distribution of the total number of storm days (*left*) and number of cells developed per storm day (*right*) for P1 and P2 areas

characteristics and similar behavior with some others. Cells initiate mainly during the day but they peak at different hours. As it was expected, in mountainous area (P1) they occur earlier than in the plain area (P2). The 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.

Cell speed differs significantly between the two areas, as relative frequency of speed peaks at 6 km/h for P1 and at 14 km/h and 20 km/h for P2. Thus, cells travel slower in mountainous area, probably due to the complex terrain and the existing obstacles. Cell direction of movement for both areas is common and mainly from southwest and northwest to northeast and southwest.

Cell precipitating area is another characteristic that also exhibits certain differences. Particularly, for non precipitating cells the relative frequency is 35% for P1 and only 15% for P2, indicating that a certain number of cells that develop over the mountainous area do not precipitate at all. Another noticeable difference appears on maximum reflectivity and cloud top values compared as a whole. Although cloud top appear to have similar behavior between the two areas, maximum reflectivity differs, with the relative frequency to peak at 52–54 dBz for area P1 and at 48 dBz for area P2, indicating that the mountainous area experiences more severe storms than the plain one. The rest of the cell characteristics, such as: cell direction, duration, volume, mass and area, show similar behavior between the two examined areas.

3.2 Monthly Comparison of Relative Frequencies

Cell characteristics that do not revealed different behavior between the two areas are further analyzed in an attempt to compare the monthly distribution of these characteristics. Therefore, the higher relative frequency values of each cell characteristic are grouped for each area and their total frequencies are monthly compared between them.

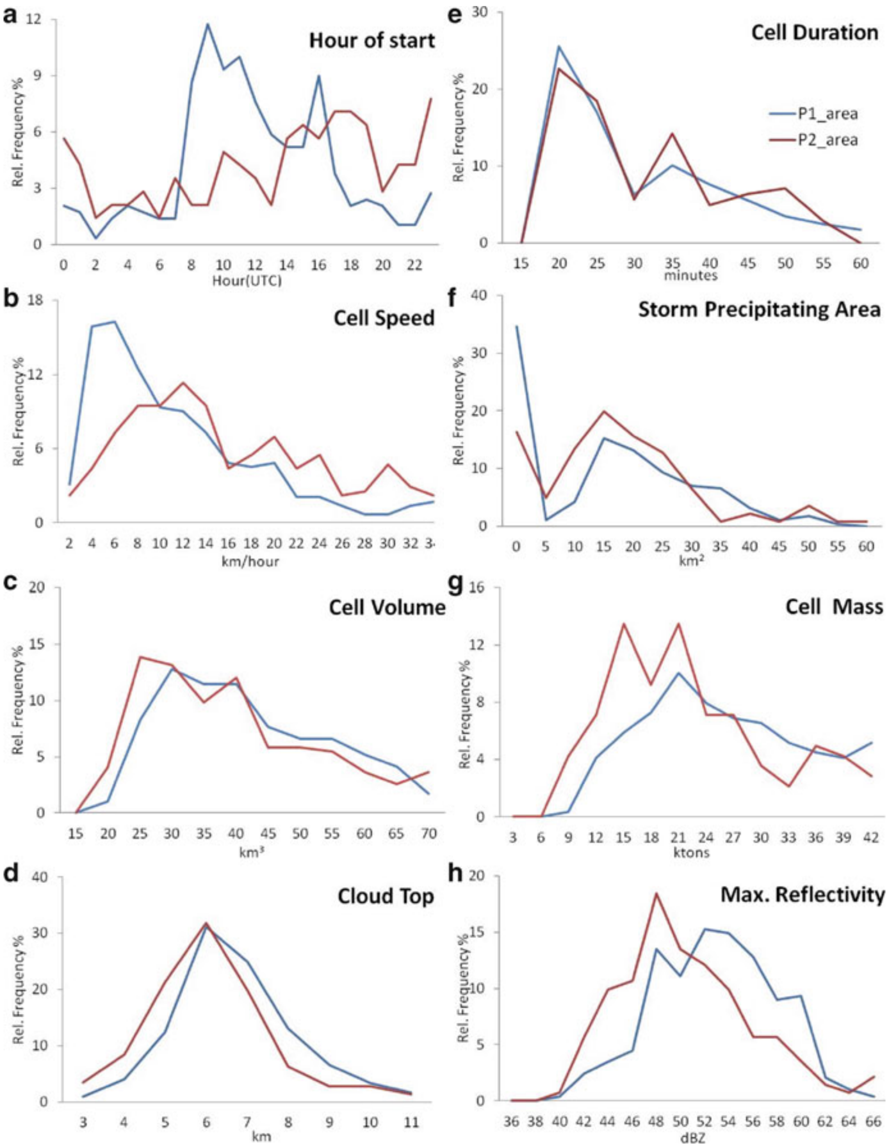

Fig. 3 Comparison of cells' relative frequencies between the two areas

Storm relative frequencies are grouped as follows: duration 15–30 min; cell volume 20–40 ktons and cell mass 10–30 km^3, for each area. The results are illustrated in Fig. 4. From the diagram of the monthly comparison of relative frequency distributions, it is observed that cell mass and volume have almost identical behavior between the two areas. Thus, cells having volume between 20 and 40 km^3 and mass 10–30 ktons appear to have lower relative frequencies in area

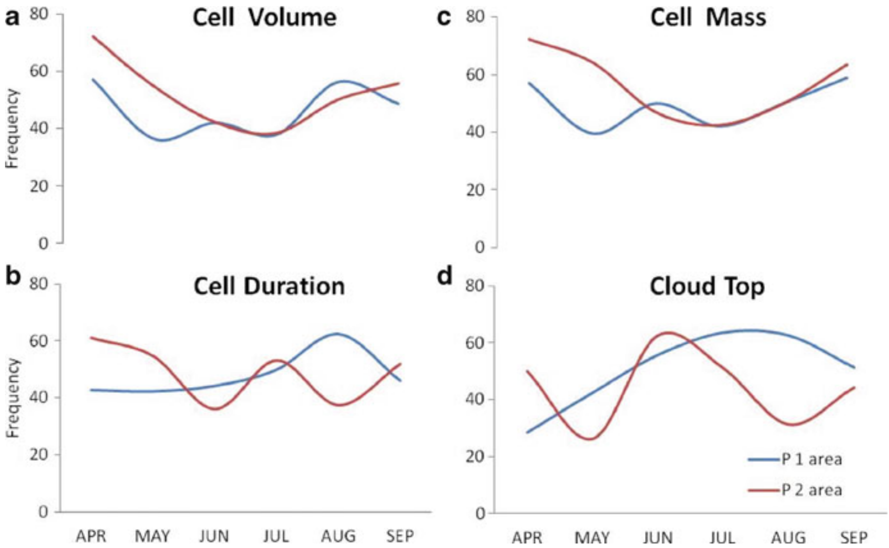

Fig. 4 Monthly distribution of relative frequencies of cell characteristics between the two areas

P1 during April and May than in area P2. Further analysis of that indicate the development of more cells with increased volume and mass during summer months for both areas, but this phenomenon is more intense for area P2.

The relative frequency of the cell duration as a function of the summer months for the two areas, also reveal some differences as seen in Fig. 4. It is observed that durations between 15 and 30 min are more frequently apparent for area P1 in August and for area P2 in April.

4 Conclusions

Cell characteristics that developed between two distinct areas in central Macedonia (mountainous and plain) are analyzed and compared. As it was expected, mountainous area experiences far more cells than the plain area, especially on July and August. Cell characteristics exhibit certain differences between the two areas of study. Cells that develop over the mountainous area (P1) appear earlier within the day, move slower and have higher maximum reflectivity values. On the other hand, cells that develop over the plain area (P2) appear later in the afternoon hours, move faster and have lower maximum reflectivity values. The 35% of the cells that develop over the mountainous area do not precipitate at all, while this percentage is only 16% over the plain area. Although cell volume and mass do not exhibit apparent differences, a closer investigation in monthly frequencies reveals that cells develop over the plain area differ more between transitional and summer months than those who develop over mountainous area. Finally, cell lifetime is almost common for both areas (20 min), but their peaks appear in August for the mountainous area and in April for the plain area.

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References

Dixon M, Wiener G (1993) TITAN: thunderstorm identification, tracking, analysis and nowcasting – a radar-based methodology. J Atmos Ocean Technol 10:785–797

Foris DV, Karacostas TS, Flocas AA, Makrogiannis TI (2006) Hailstorm in the region of Central Macedonia, Greece: a kinematic study. Meteor Z 15:317–326. doi:10.1127/0941-2948/2006/0134

Karacostas TS (1991) Some characteristics of convective cells in the Greek National Hail Suppression program. Geofizika 8:43–50

Sioutas MV, Flocas HA (2003) Hailstorms in Northern Greece: synoptic patterns and thermodynamic environment. Theor Appl Climatol 75:189–202. doi:10.1007/s00704-003-0734-8