COMPARISON OF THE HAILSTORM CHARACTERISTICS BETWEEN TWO DIFFERENT AREAS IN GREECE

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Abstract: The Greek National Hail Suppression Program using airborne seeding is applied in Central Macedonia and Thessaly in the period April to September, covering an area of 5,000 square kilometers. In the present study, the storm characteristics of the two protected target areas, during the period April to August 2005, are described and are compared. The analysis utilizes radar data recorded by the TITAN system. The results will contribute to the knowledge of the storms in the area.

1. INTRODUCTION

In the present study the storm characteristics are examined and are compared for two different areas in Greece. The areas, about equal in size, are the project areas, Area-1 and Area-3 and 3b (shown in Figure 1), where the Hellenic Agricultural Insurance Organization (EL.G.A) applies the Greek National Hail Suppression Program (GNHSP) using airborne seeding. (Tzoumaki, 2006). The aim of the study is the contribution to the knowledge of storms in the area and consequently to the planning phase of a pilot hail suppression project with the use of ground generators for cloud seeding, which EL.G.A has decided to implement.

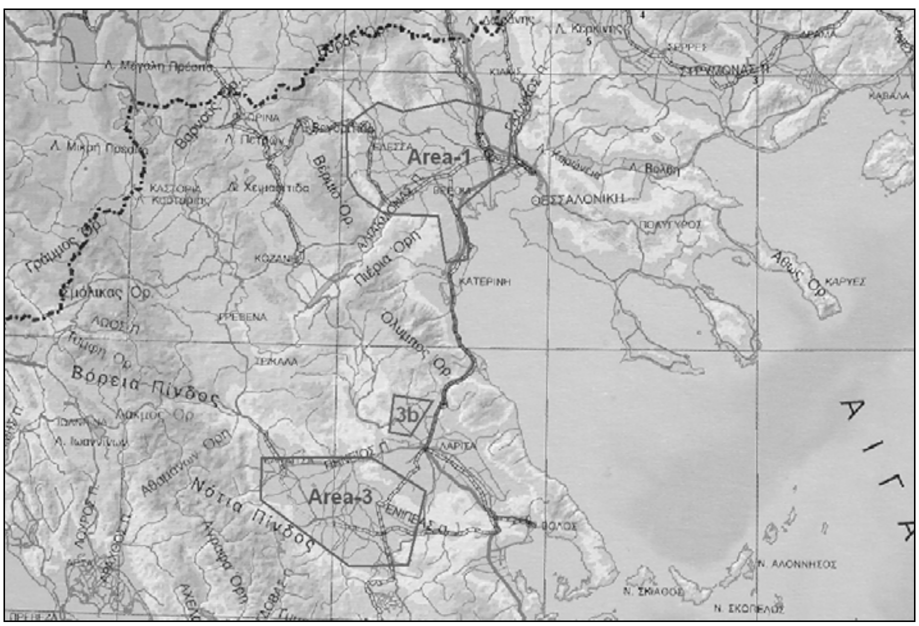

Figure 1: A map of northern Greece showing the location of the two project areas Area 1 and Area 3, 3b of the GNHSP.

2. CHARACTERISTICS OF STORM CELL COMPLEXES

The analysis utilizes radar data of the EEC S-band meteorological radars installed at Macedonia and Larissa Airports. It is mentioned that the distances of the radars from the center of the relevant target areas are about the same. The same procedure of calibration, providing both radars about the same level of sensitivity, is also followed. The data recorded by TITAN, Thunderstorm, Identification, Tracking, Analysis, and Nowcasting system described by Dixon and Wiener (1993), are being analyzed, creating a sample of Storm Cell Complexes structured data for each area. The data were recorded during the storm activity from April to August 2005.

Storm Cell Complexes (SCC) are defined as Radar echoes, convective in nature, with cell reflectivity equal or greater than 35 dBZ at the -5^0 C level or higher. The reflectivity threshold of 25 dBZ at the -5^0 C level or higher was used to identify the beginning and the end of the cell in the case where the SCC is consisted by one cell, and the beginning of the first and the end of the last cell respectively, when the SCC is consisted by more than one cells.

The SCC are composed of short-lived units of convection, referred to as ordinary cells and rarely of much more vigorous units of convection known as supercells.

Every SCC is identified with one of the classes of the primary and secondary hailstorm classification according to Browning (1977). The SCC categories are the Unicellular type that may consist of a Single isolated ordinary cell or a Supercell, the Multicell type with a cluster of cells, not forming in a distinct line, and the Line type containing cells along a line.

A Supercell type is a unicellular SCC with a single isolated supercell, which is long lived, severe, and shows a vault in a cross section. In the two observed cases they had started as multicell but gradually merged in a cell.

A typical Multicell type contains two or more radar cells at any given time, which are at a different evolution stage. New radar cell grows rapidly on the flank of the mature cell and becomes the storm center, meanwhile the previous cell begins to decay while another forms.

The Line contains cells along a line, moving perpendicular to its axis. A Multicell or a Line usually contains ordinary cells and rarely a mixture of ordinary cells and supercells.

In the sequence, the symbol “S” will be used for the Unicellular storms of a single ordinary cell, the symbol “SU” for the Unicellular storms of a Supercell, the symbol “M” for the Multicell storms and the symbol “L” for the Line storms.

A meteorologist, who was the radar data analyzer, did the SCC selection.

The SCC characteristics, which were examined, are:

- The SCC date of occurrence
- SCC number
- First appearance (“first echo”) time (UTC), when maximum radar reflectivity was 25 dBZ at the -5^0 C level or higher,
- Dissipation time (UTC), when maximum reflectivity became less than 25 dBZ at the -5^0 C level or higher
- Life time (min), subtracting the First appearance time from the Dissipation time
- “First echo” Region, in the project area or in the buffer zone using the West (W), North (N), East (E) and South (S) part of it in relation to the project area
- Storm classification Type
- Maximum reflectivity (dBZ) at the -5^0 C level or higher during entire lifetime
- Maximum height (Km) of the cloud top during the entire lifetime
- Motion: Direction - from (azimuth) and Speed (Km/h)

3. ANALYSIS

The monthly distribution of SCC and SCC days per area are given in Table 1. A SCC day is defined as a day when at least one SCC was recorded in the area by radar.

The daily distribution of SCC per area, within 3-hour time intervals in UTC (local time is equal to UTC plus 3 hours), is shown in Figure 2.

TABLE 1: Monthly distribution of SCC and SCC days

	Number of SCC days		Number of SCC	
Month	Area-1	Area-3, 3b	Area-1	Area-3, 3b
April	0	1	0	3
May	9	9	42	73
June	4	4	10	8
July	12	5	39	17
August	5	5	33	24
Total	30	24	124	125

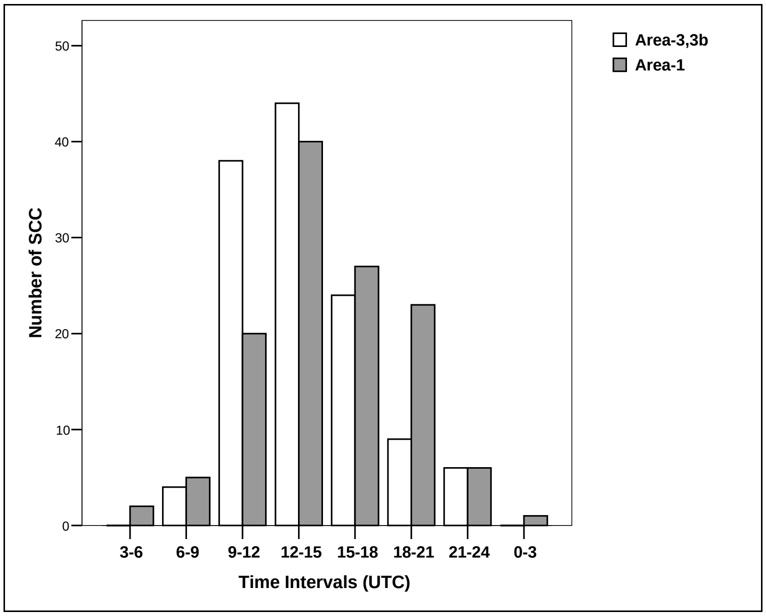

Figure-2: Frequency histogram of SCC according to time of day (UTC).

Table 2 gives the SCC “First echo” region per area, in the Area and in the north (N), west (W), south (S) and east (E) part of the buffer zone. It is remarked that only in this spatial distribution, the Area-3 is divided in the big part of Area-3 and in the small part, called as Area-3b, for more detail examination.

TABLE 2: SCC “First echo” regional distribution.

	Area-1		Area-3		Area-3b	
	Number	%	Number	%	Number	%
In Area	75	60.5	63	50.4	7	5.6
N buffer	8	6.5	31	24.8	4	3.2
W buffer	17	13.7	4	3.2	5	4
S buffer	11	8.9	6	4.8	0	0
E buffer	13	10.4	5	4	0	0
Total	124	100 %	109	87,2%	16	12,8%

Table 3 gives the SCC direction of movement distribution using the eight classes of azimuth orientations, e.g. a storm motion from the northeast is shown by the symbol NE and the stationary case with the symbol ST and Table 4 gives the SCC types per area.

TABLE 3: SCC Direction of movement distribution.

		N	NE	E	SE	S	SW	W	NW	ST
Area-1	No.	14	7	19	7	20	11	37	4	5
	%	11.3	5.7	15.3	5.7	16.1	8.9	29.8	3.2	4
Area-3, 3b	No.	35	45	2	0	5	12	7	8	11
	%	28	36	1.6	0	4	9.6	5.6	6.4	8.8

TABLE 4: SCC Types according to Area.

	Area-1		Area-3, 3b	
	Number	%	Number	%
S	54	43.5	47	37.6
M	70	56.5	75	60
SU	0	0	2	1.6
L	0	0	1	0.8

In the Table 5 are presented the statistics, including the mean (M), standard error (SE), minimum (Min), maximum (Max), lower (L) and upper (U) bound of the 95% confidence intervals of the mean and the total number (N) of SCC for the Life time (L.T.), Maximum Reflectivity (R), Maximum Height (H) and Speed (V) per area.

TABLE 5: Statistics of SCC Life time, Reflectivity, Height and Speed according to Area.

	Area-1				Area-3, 3b			
	L.T. (min)	R (dBZ)	H (Km)	V (Km/h)	L.T. (min)	R (dBZ)	H (Km)	V (Km/h)
M	55.1	50.3	8.9	26.4	69.1	53.7	8.5	18.3
SE	1.98	0.54	0.14	1.23	3.39	0.51	0.14	0.91
Min	22	39	5.5	0	19	35	5.5	0
Max	137	69	12	61	211	68	13	43
L	51.8	49.4	8.7	24.4	63.5	52.8	8.3	16.8
U	58.4	51.2	9.2	28.4	74.8	54.5	8.8	19.8
N	124				125			

The Kolmogorov – Smirnov test was applied and the Normal Probability plots were used to check the normality assumption for the distributions of the above four parameters in Area-1 and Area-3, 3b. The results show that the normality holds only for the Speed ($p > 0.20$). Therefore, the t-test applied for the Speed to check the difference in means between the two areas and the non-parametric Mann – Whitney test for the Lifetime, Reflectivity and Height.

In the first case, the Levene's test showed that equal variances were not assumed ($F=5.974$, $p = 0.015$) and the relevant t-test showed that, the difference in means of the Speed between the two areas was statistically significant ($t=5.254$, $df=227.95$, $p < 0.001$).

In the second case, the non-parametric Mann – Whitney test showed that the differences in means of the Lifetime and Reflectivity between the two areas were statistically significant ($U=6102.5$, $p = 0.004$ and $U=5085$, $p < 0.001$ respectively) whereas the corresponding difference of the Height was not ($U=6732.5$, $p = 0.071$).

Using 0.05 as the significance level led to all the above results. However if 0.10 had been selected as the significance level, the difference in means of Height between the two areas would have been indicated as statistically significant ($p = 0.071$). The statistical software of SPSS was used for the above analysis.

4. CONCLUSIONS

From the analysis above, comparing the values of the parameters that characterize the storm activity in the Area-1 and Area-3 we can make the following conclusions.

The number of SCC for Area-1 (124) is about equal with the number for Area-3, 3b (125), but the number of SCC days is greater (30 for Area-1 and 24 for Area-3, 3b). From the monthly distribution can be noted that the greatest number of SCC days was recorded in July (12) for Area-1, however the greatest number of SCC was 73 during 9 days in May for Area-3, 3b. For Area-1, the greatest number of SCC occurred in May (42). For Area-3, 3b, May recorded the greatest number of both SCC (73) and SCC days (9).

From the daily distribution can be noted that the afternoon hours from 09:00 up to 15:00 UTC (12 to 18 local time), the number of SCC for the south Area-3, 3b is greater than for the north Area-1 and the opposite happens for the rest of the day. In the 12:00-15:00 UTC interval (15 to 18 local time) was recorded the greater number of SCC for both areas.

From the SCC "First echo" region distribution it is noted that in both areas the greater number of SCC has the first appearance inside the areas (60.5% for Area-1 and 56% for Area-3, 3b), while the second region is the west part of the buffer zone (13.7%) for the Area-1 and the north part (28%) for the Area-3, 3b.

The 29.8% of the SCC for Area-1 have direction of movement from west and 36% for Area-3, 3b from northeast.

In both areas the Multicell storms are the most frequent type of SCC, which has been recorded. In the Area-1, only Unicellular storms and Multicell storms were observed, while in the Area-3, 3b all the types of SCC and specifically, one case of Line storms and two cases of Unicellular storms of a Supercell were observed.

The SCC cloud top Height for Area-3, was less than the mean Height for Area-1 but the differences were not significant. The mean SCC Reflectivity and Lifetime were significantly greater for Area-3 than Area-1, while the Speed was significantly less.

The 2005 storm season was the most active season in the history of the GNHSP. These results are only based on one year, therefore, more years should be analysed to see if these results are representative of the longer-term climatology for the region.

5. REFERENCES

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