Lightning behaviour during the lifetime of severe thunderstorms

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I. INTRODUCTION

Several studies (Williams et al., 1999; Lang et al., 2000; Soula et al., 2004, etc.) established a relation between lightning characteristics and severe events such as tornado and large hail. The limited number of studies concerning lightning activity of thunderstorms developed over Bulgaria showed that there is a significant difference between lightning characteristics in thunderstorms, producing hail, heavy and weak rain.

The present work is directed to study if there are peculiarities in lightning characteristics during the lifetime of different types of severe hail producing thunderstorms developed over Bulgaria.

II. DATA

Combined analyses of lightning and radar data for three severe thunderstorms developed over Bulgaria during the summer of 2009 and 2010 have been carried out.

The genesis of the studied thunderstorms was different. One of them was a multi-cellular storm (MC). The other one was an isolated developed supercell (SC), while the third one was multi-cellular and evolved into a supercell storm (MSC). The lifetimes of the thunderstorms were longer than 2 hours. There is a significant difference in the duration of large hail falling on the ground from the three thunderstorms – 60 min from MC, 15 min from SC and 26 min from MSC. The MC and SC thunderstorms produced hailstones with diameter up to 3 cm and MSC up to 6 cm.

Lightning data are taken from the LINET network (Betz et al., 2008). Radar information is obtained by S-band Doppler radar MRL5-IRIS from the Hail Suppression Agency in Bulgaria. The flash rate is calculated per 4 minutes in accordance with the period of the radar volume scan.

List of symbols

FR	– flash rate	**Mn**	– multiplicity
H15	– height of 15 dBZ reflectivity	**H45**	– height of 45 dBZ reflectivity
Hzmax	– height of maximum reflectivity	**H0**	– height of 0°C isotherm

III. RESULTS

The highest lightning activity (flash rate and multiplicity) is observed during the lifetime of the evolved from a multi-cell into a supercell MSC thunderstorm. The mean and maximum values of FR, as well as the multiplicity of negative strokes in MC and SC are remarkably lower than in MSC.

	Flash rate per 4 minutes						Multiplicity			
	Positive		Negative		Total		Positive		Negative	
	mean	max	mean	max	mean	max	mean	max	mean	max
MC	1.2	2	9.9	23	10.1	24	1	1	1.2	6
SC	2.1	5	4.9	15	6.0	15	1	1	1.3	7
MSC	11.2	38	27.8	80	38.8	113	1.1	3	1.8	16

- There is a positive time lag between the jumps of both flash rate (Fig. 1) and multiplicity of negative strokes (Fig. 2) and large hail falls in the three analysed thunderstorms.
- The jump of FR in MC and MSC is accompanied by a sharp increase of H15 and H45. During the large hail falls, the FR decreases in MSC and SC but reached maximum values in MC (Fig. 1).
- The maximum values of multiplicity of negative flashes in the three storms are before the falling large hail on the ground (Fig. 2). The highest value of 16 is registered in MSC while maximum values in MC and SC are 6 and 7, respectively .

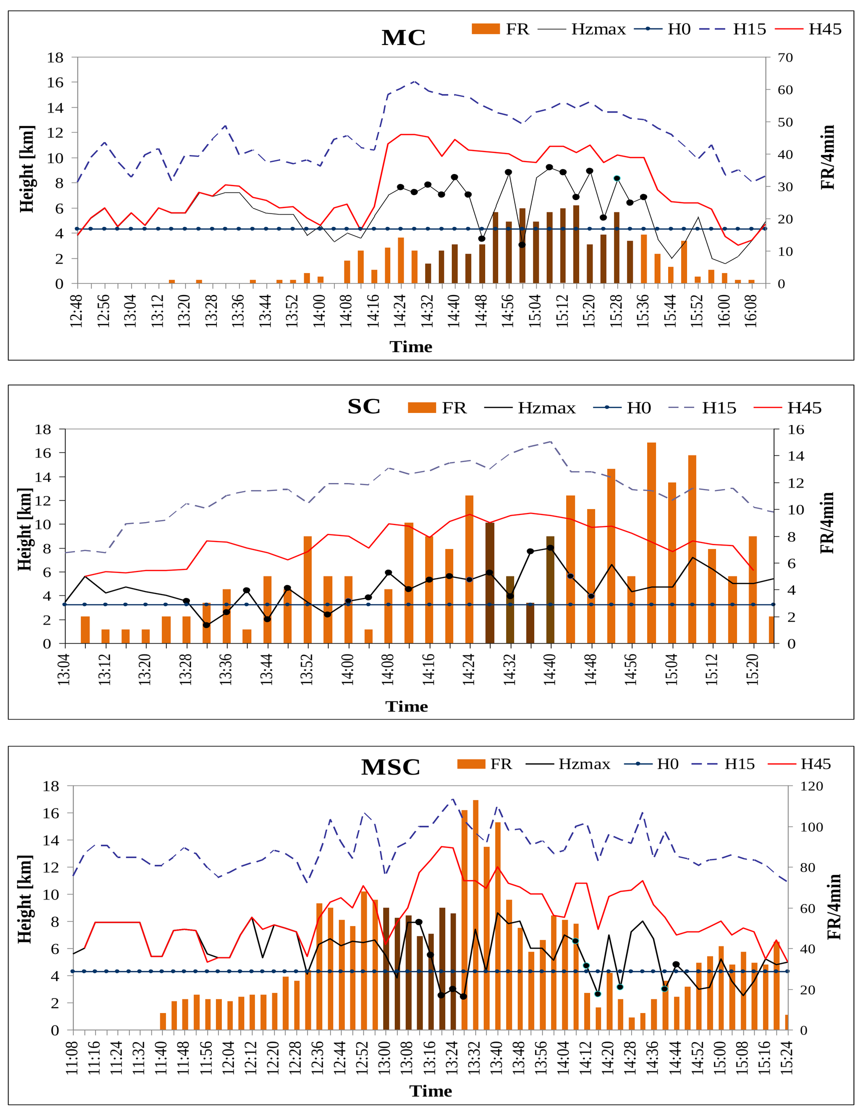


FIG.1: Number of flashes per 4 minutes, FR, and radar information as a function of time. The FR during the period of intensive large hail on the ground is denoted by darker columns. The maximum radar reflectivity reached 60-65 dBZ is marked by dots on the curve of Hzmax.

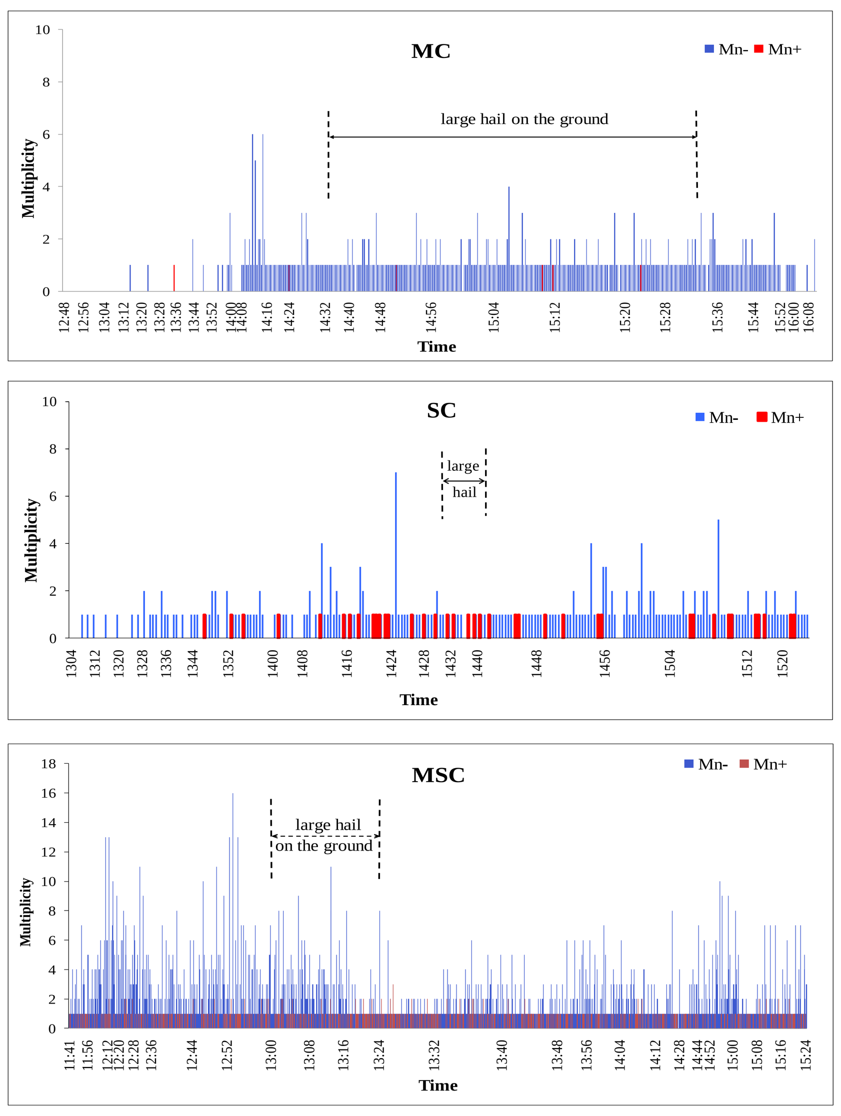
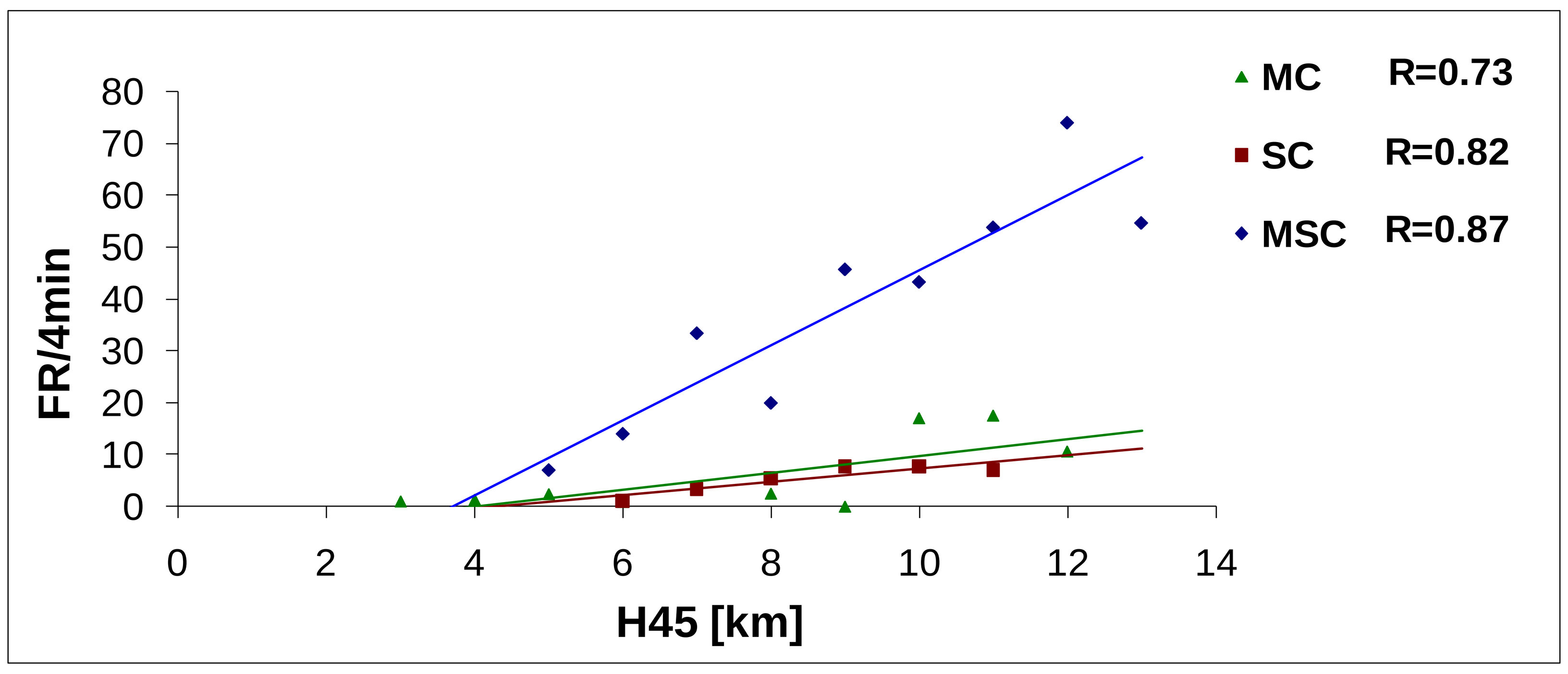
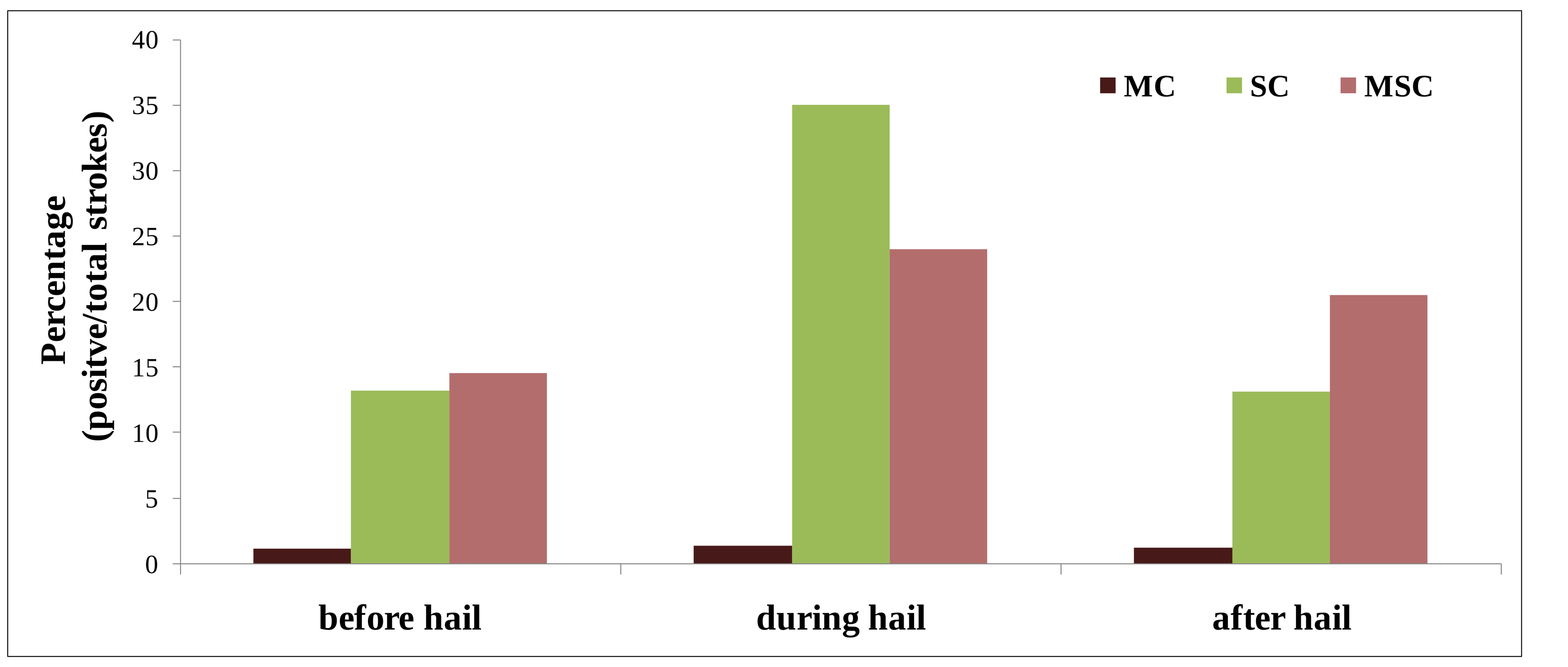


FIG. 2: Multiplicity of positive flashes, Mn+ and negative flashes, Mn− as a function of time





- A correlation between H45 and FR averaged in 1 km bin is established.

Based on the assumption that the radar volume fraction for graupel correlates with the volume of reflectivity 45 dBZ, one can speculate that these results are consistent with the non-inductive charging mechanism (Saunders, 1993).

- Positive strokes were detected in all three thunderstorms.
- During the entire analysed period of lightning activity, the percentage of positive strokes in MC is very low (≈1%), while in SC and MSC it is approximately 20%.
- The percentage of positive strokes is highest during the period of large hail detected on the ground.

IV. CONCLUSION

The main results are:

- There is a positive time lag between the jumps of both multiplicity and flash rate and large hail falls in the three analysed thunderstorms.
- Significant numbers of positive strokes are detected in both supercells SC and MSC. The highest percentage of positive strokes is observed during the period of large hail on the ground.
- The highest lightning activity (flash rate and multiplicity) is observed during the lifetime of the evolved from a multi-cell into a supercell MSC thunderstorm. The mean and maximum values of FR, as well as the multiplicity of negative strokes in MC and SC are remarkably lower than in MSC.

The present study reveals that most of the lightning signatures in the studied severe thunderstorms developed over Bulgaria are similar to those in other geographical regions. The established jump in the flash rate before large hail fall is in accordance with the results reported by Soula et al. (2004), Kane (1991), and Williams et al.(1999). The detected significant numbers of positive strokes in both supercells correspond to the results obtained by other authors (e.g. MacGorman and Burgess, 1994; Stolzenburg, 1994; Carey and Rutledge; 1998, Lang et al., 2004; Wiens et al., 2005) and according to MacGorman and Burgess (1994) this can be explained by the structure of supercell storms. One can speculate that the significant difference in flash rate in MSC, SC and MC thunderstorms supports the conclusion by Fehr et al. (2005) that the convective organization plays a crucial role in the lightning development.

To answer the question if there is a relationship between an extremely high flash rate in MSC (FR>100 per 4 min) and extremely large hail (greater than 6 cm), more hail producing thunderstorms developed over Bulgaria have to be analyzed.

V. AKNOWLEGMENTS

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