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LIGHTNING INCIDENCE TO ELEVATED OBJECTS ON MOUNTAINS

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Abstract

Several spots of significant high flash density have been discovered in Austria. Most of these spots are associated with different types of radio towers on top of mountains.

We have analyzed flashes that have been detected from a lightning location system during a period of two years at a distance of less than 1 km from radio towers. Most of these flashes are assumed to be direct strikes to the tower. In average their peak amplitudes and their number of subsequent strokes are significantly higher compared to flashes to ground in the vicinity of the tower.

1. Introduction

The lightning location system ALDIS is in operation in Austria since 1992. The system was upgraded to the so called IMPACT technology in 1994 providing sufficient location accuracy in the range of 500 m to 1000 m to investigate differences in the local flash density in more detail.

In the previous literature we can find different approaches to estimate the effect of tall structures on the flash incidence [1,2] . Influence of a tall structure upon the lightning mechanism (tall structure on flat ground or structure on top of a mountain) is caused by the increase of the electrostatic field. Breakdown field on top of the structure is exceeded by the proximity of a descending leader or the charges in the thundercloud itself. Similar to artificially triggered lightning tall structures on mountains favor the initiation of upward lightning (Ground to Cloud). In many cases in a lightning channel established by an upward lightning, a number of downward subsequent strokes (Cloud to Ground) are observed.

2. Local ground flash density in the vicinity of a radio tower

The Austrian lightning location system provides information about the location (latitude/longitude), the peak current and the number of subsequent strokes. For all located ground striking flashes the average accuracy of the Austrian location system was determined by different theoretical and experimental approaches to be in the range of several hundred meters. With this location accuracy it is reasonable to analyze the local flash density based on a grid size of 100 m x 100 m.

Evaluation of the local ground flash density in 1995 and 1996 revealed several spots of significantly increased lightning flash density compared to the surrounding distributed all over Austria. An example of such a spot is shown in Figure 1, where the flash density (number of flashes per km^2 and year) is plotted for an area of 20 km x 20 km around a mountain top near the city of Salzburg called “Gaisberg”. On top of that mountain (1288 m above sea level) a radio tower of a height of 100 m is located. Location of the tower (13,11056°E/47,8047°W) corresponds with the center (0/0) of the plot in Fig. 1. Except for the tower site itself the flash density is less than 5 flashes per km^2 per year over the entire area of 20 x 20 km^2.

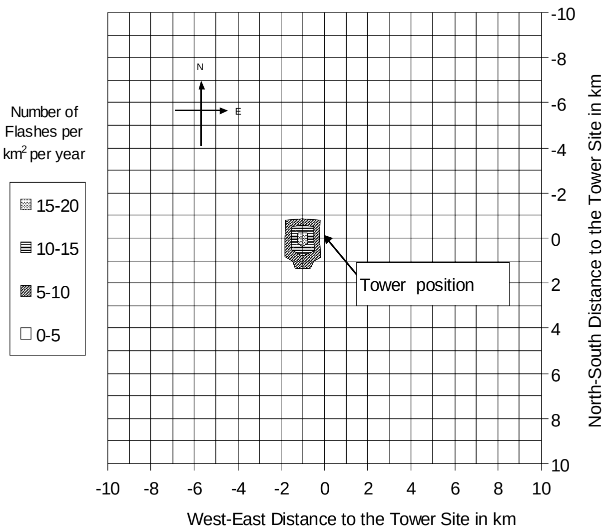

Fig. 1: Lightning flash density in the area of the Gaisberg tower (47.8047°N / 13.11056°E, 1288 m above sea level)

In the vicinity of the tower we observe a flash density of about 13 flashes per km^2 and year. This significant increase in local flash density is certainly caused by a triggering effect of the tower of 100 m on top of the mountain.

We have to note that the flash density N_g expressed as number of flashes per km^2 and year in case of a very local increase is not a proper way to specify the lightning risk. The value of N_g is biased by the grid size chosen for this evaluation. For a grid size smaller than 1 km N_g is overestimated because a uniform flash density is assumed over the 1 km x 1 km area.

The average ground flash density N_g in a circular area of 2 km < R < 20 km excluding the tower itself is determined with N_g=1,4 flashes/km^2.a. From this value N_g, we can calculate the number of flashes N_d striking the tower by Eq. (1) [2]

$$N_d = N_g * 2.4 * 10^{-5} * h^{2.05} \qquad (1)$$

where h is the height of the structure in m. For a tower of 100 m height Eq.(1) gives N_d = 0,423.

The total number of flashes located by ALDIS in the area 0 km < R < 1 km in 1995 and 1996 was 83. 29 flashes during 9 thunderstorms in 1995 and 54 flashes during 17 thunderstorms in 1996 were located. We assume that most of these flashes have been direct strikes to the tower. This number is much higher than the number N_d calculated from Eq. (1) only predicting about 1 flash in 2 years.

Based on the physical background of the effects of a tall structure to the local flash density it is rather the decreased distance to the base of the thunder-cloud than the absolute height of the tower. Although Eq.(1) is limited to structure heights between 20 m and 500 m we can calculate the number N_d assuming a "structure height" of 1000 m. 1000 m is about the total elevation of the mountain Gaisberg and the tower relative to the surrounding. With this height h = 1000 m using Eq.(1) we calculate N_d = 47. This number is at least in the range of the actually observed number of direct strikes to the tower.

3. Peak current distribution

Most of the available statistical data on lightning current parameters are the result of direct current measurements on towers [e.g. 1,3]. There is still discussion whether these data are biased by the elevated object on a mountain or they are also valid for a flat area.

In Fig. 2a and Fig. 2b comparison of the peak current distribution of first strokes to the nearby tower (0 km < R < 1 km) and of first strokes to the surrounding (1 km < R < 10 km) is shown. Due to the comparison of peak currents - or better peak magnetic fields - in a very limited region the effects of field propagation over ground of finite conductivity are excluded. The direction finders of the location system are at distances of 100 to 200 km and all the radiated fields from flashes in the region R<10 km around the tower site are assumed to be attenuated about the same way along this propagation path. The mean value of -16,0 kA (N=81) for first strokes to the tower is significantly higher than the mean value of -12,9 kA (N=686) for first strokes in the vicinity of the tower.

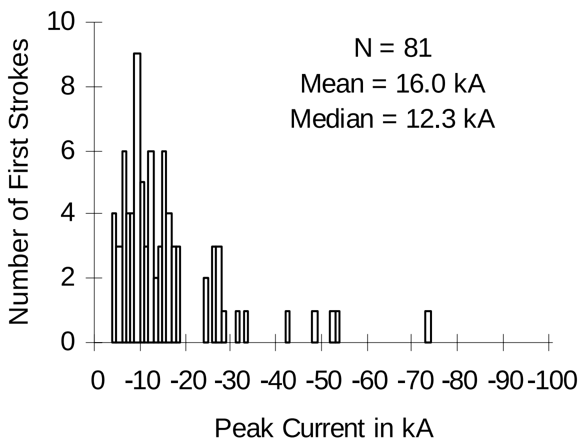

Fig. 2a: Peak current distribution for first strokes located in an area of 0 km < R < 1 km around the tower position

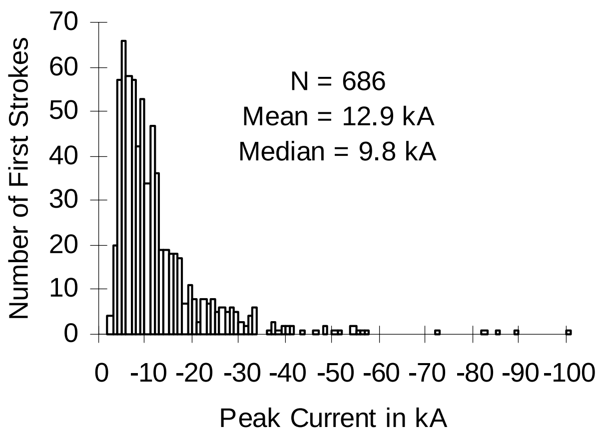

Fig. 2b: Peak current distribution for first strokes located in an area of 1 km < R < 10 km around the tower position

A similar comparison was done for three other radio towers located at different altitudes in the Austrian mountains. All these towers exhibit a significant increase in local flash density. Differences in the mean values I_1 and I_{10} of the peak current distributions have been proven by a T-test to be statistically significant. Results are summarized in Table 1.

We have to note, that these results are independent of the accuracy of the conversion of measured peak fields to peak currents because it is a relative comparison of measured signal strength.

Table 1: Difference of the mean peak current to elevated objects

Site	Tower height [m]	Altitude above see level [m]	N (R < 1 km)	N (1 km < R < 10 km)	I_1 [kA] for R< 1 km	I_{10} [kA] for 1 < R < 10 km	ratio I_1/I_{10}
Gaisberg	100	1287	81	686	-16.0	-12.9	1.24
Dobratsch	165	2166	176	1220	-16.0	-13.0	1.22
H. Salve	50	1828	40	1019	-21.3	-16.6	1.29
Kitzbühel	53	1996	128	1137	-14.6	-14.5	1.00

In Table 1 we can see an average increase of the mean peak current of flashes to the tower by about 20 - 25 %.

4. Number of subsequent strokes

A histogram showing the number of strokes per flash for the two distinct regions 0 km < R < 1 km and 1 km < R < 10 km is presented in Fig. 3 for the location Gaisberg. Obviously the flashes to the tower have a significantly higher stroke number than the flashes to ground in the vicinity of the tower.

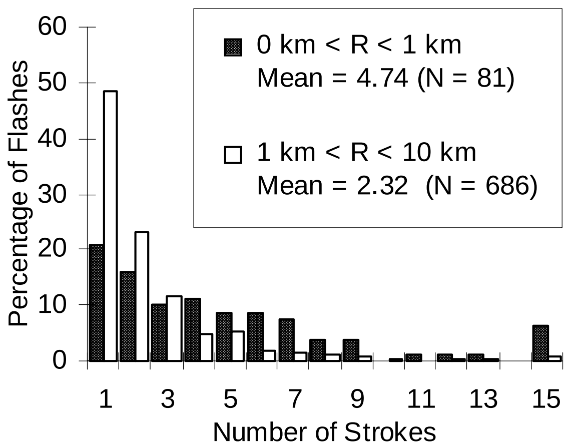

Fig. 3: Number of strokes per flash around the Gaisberg tower

A mean of 4,74 strokes per flash to the tower (R < 1 km) is about twice the mean of 2,32 strokes per flash in the vicinity. In general there is a decrease in the percentage with an increasing number of strokes. Because the direction finder is only able to detect up to 15 strokes per flash the increase in Fig. 3 for 15 strokes in a flash for R < 1 km is an indication for the existence of a significant number of flashes having more than 15 strokes - all these flashes are assigned as 15 stroke flashes.

In Table 2 we have summarized the data regarding the number of strokes per flash for the same four locations as shown in Table 1.

Table 2: Multiplicity for different locations

Location	Multiplicity (R < 1km)	Multiplicity (1 km < R < 10 km)
Gaisberg	4.74	2.32
Dobratsch	6.48	2.54
Hohe Salve	4.55	2.73
Kitzbühel	3.95	2.66

All four locations exhibit a significant increase of mean multiplicity. At the Dobratsch tower with a height of 165 m a maximum for the average multiplicity of 6.5 was observed.

4. Summary and discussion

Evaluation of the local flash density in the vicinity of radio towers on top of mountains revealed a significant number of flashes to the towers causing a local increase of the calculated flash density N_g. This data confirm the triggering effect of elevated objects on mountains. We have shown, that for an estimation of the number of strikes to a tall structure on a mountain the total elevation of the mountain and the structure seems to be more relevant than the structure height itself.

Comparison of peak current distribution and average number of strokes per flash revealed a significant effect of the structure and/or elevation to both of these parameters. In average lightning peak currents to towers are about 20 % higher than to the vicinity of the tower. Average multiplicity of flashes to towers on mountains is almost twice as the average multiplicity observed to flat ground.

References

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