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# AREAS OF INCREASED LIGHTNING FLASH DENSITY ON MOUNTAIN TOPS

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Résumé

Plusieurs points de densité de foudroiement très élevée ont été découverts en Autriche. La plupart d'entre eux sont associés à divers type de tours d'émission radio situés au sommet de montagnes. Dans cet article l'effet déclencheur des structures élevées est confirmé.

Comme exemple, nous avons analysé en détail les données issues d'un réseau de localisation de la foudre pour l'un de ces points. 81 éclairs ont été détectés au cours d'une période de 2 ans et à moins de 1 km de la tour. La plupart de ces éclairs sont considérés comme des coups directs à la tour. En moyenne, leur amplitude crête et leur nombre d'arcs en retour sont supérieures aux valeurs des impacts relevés au voisinage de la tour.

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. In this paper the triggering effect of tall structures is confirmed.

As an example we have analyzed the data from a lightning location system for one of these spots in more detail. 81 flashes have been detected during a period of two years at a distance of less than 1 km from a radio tower. 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 higher compared to flashes to ground in the vicinity of the tower.

## 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 to investigate differences in the local flash density in more detail.

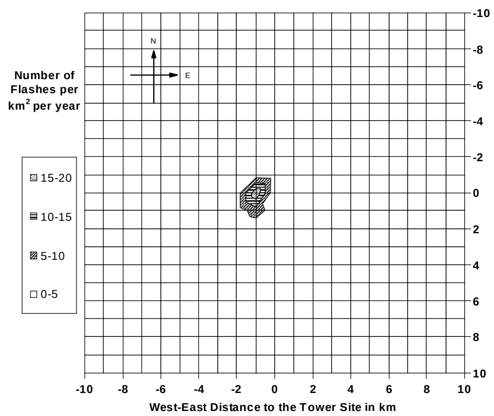
In the previous literature we can find different approaches to estimate the effect of tall structures on the flash incidence [1,2]. Influence of a tall structure upon the lightning mechanism (tall structure on flat ground or structure on top of a mountain) is caused by the increase of the electrostatic 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.

## Local ground flash density

The Austrian lightning location system provides for all located ground striking flashes information about the location (latitude/longitude), the peak current and the number of subsequent strokes. The average accuracy of the 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 distributed all over Austria with a significantly increased lightning flash density compared to the surrounding. 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 much less than 10 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 “Gaisberg” (47.8047°N / 13.11056°E, H = 1288 m)

In the vicinity of the tower we determine a flash density of about 13 flashes per km$^2$ per year. This significant increase in local flash density is certainly caused by a triggering effect of the 100 m tower on the 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 the 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 2 km < R < 20 km excluding the tower itself is determined with $N_g$=1,4 flashes per $km^2$ per year (Fig. 2). 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 meter.

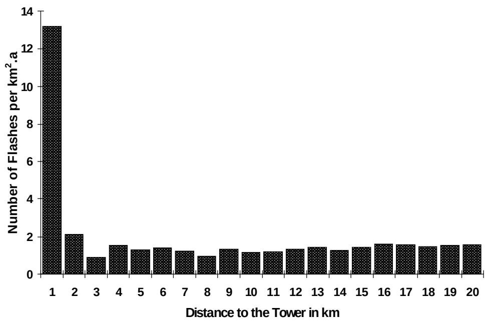



Fig. 2: Ground flash density $N_g$ as a function of distance

For a tower of 100 m height we calculate a $N_d$ = 0,423 direct strikes to the tower per year.

The total number of flashes located by ALDIS in the area 0 km < R < 1 km in 1995 and 1996 was 83. In 1995 during 9 thunderstorms 29 flashes and 54 flashes during 17 thunderstorms in 1996 were located. We assume that most of these flashes were 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) in [2] 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 we calculate $N_d$ = 47. This number is at least in the range of the actually observed number of direct strikes to the tower.

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.

The lightning location system detects the peak magnetic field and applies a correlation of the form

$$I_p = K * S_n \qquad (2)$$

to estimate the peak current for the individual strokes, where $S_n$ is the range normalized signal strength reported by the direction finders [4]. For the Austrian lightning location system a value K = 0,23 is used. This is the value recommended by the manufacturer of the system. The value K = 0,23 is close to values determined by the correlation of measured peak currents from triggered lightning and location system data [4].

In Fig. 3a and Fig. 3b the peak current distribution of the first strokes to the tower (0 km < R < 1 km) and of first strokes to the surrounding (1 km < R < 10 km) is shown respectively. The mean value of -16,0 kA (N=81) for the 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. 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 the same way along this propagation path.

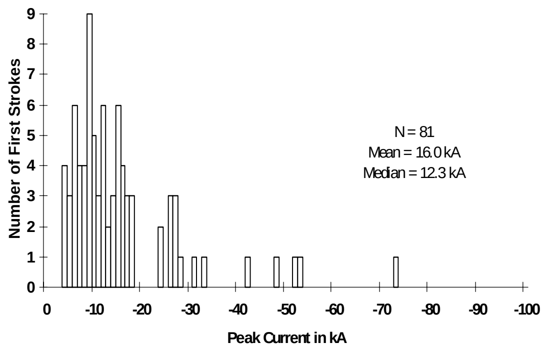



Fig. 3a: Peak current distribution 0 km < R < 1 km (tower)

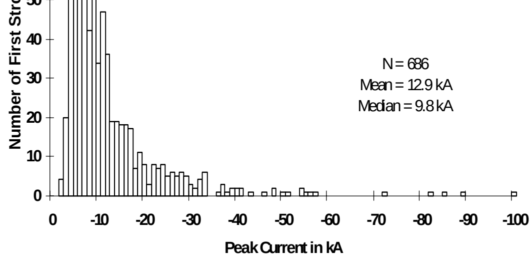



Fig. 3b: Peak current distribution 1 km < R < 10 km (vicinity)

Number of subsequent strokes

The number of strokes per flash for the two distinct regions 0 km < R < 1 km and 1 km < R < 10 km is shown in Fig. 4. Obviously the flashes to the tower have a significantly higher stroke number than the flashes to ground in the vicinity of the tower.

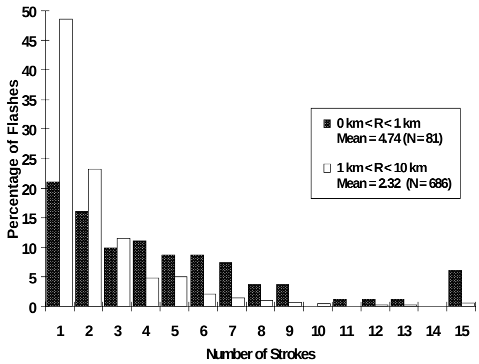



Fig. 4: Number of strokes per flash

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 to 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. 4 for 15 stroke flashes 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 reported as 15 stroke flashes.

Summary and discussion

Evaluation of the local flash density in the vicinity of a radio tower on top of a mountain revealed a significant number of flashes to the tower causing an increase of the calculated flash density $N_g$. This data is a confirmation of 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.

References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