Paper presented at the International Conference on Lightning and Static Electricity,
Toulouse, France, 1999

Lightning Characteristics as a Function of Altitude Evaluated from Lightning Location Network Data

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Abstract:
Many analyses of lightning parameters and lightning densities are found in literature. Most of the data are based on single station measurements and therefore, strictly speaking, they are only valid for a certain altitude. With lightning location systems it is possible to collect and analyze lightning parameters over large areas. For such analyses, a lightning location network of high detection efficiency over a large area is necessary. Because the Austrian lightning location network is a network of small baselines it has a very high detection efficiency and is therefore ideal for such an investigation. In this paper we show preliminary results of lightning density and lightning peak current as a function of altitude above sea level in Austria.

1. Introduction
The Austrian lightning location system is one of the best performing lightning location systems (LLS) in the world. The network is comprehensively described in Diendorfer et al. [1998] and Schulz [1997].

The correlation of lightning flash density and lightning peak currents with altitude requires a digital elevation model. We chose the GLOBE model (http://www.ngdc.noaa.gov/seg/topo/globe.shtml) which gives elevations above sea level based on WGS84 datum. The locations reported by the LLS are also in the same datum. The elevations given by the model are average values of altitude over squares of a size of 30 arc seconds longitude and 30 arc seconds latitude. The 30 arc second latitude-longitude grid spacing of the data set is somewhat finer than one kilometer spacing on the ground.

2. Area of investigation
The Austrian Lightning location system is a high gain network with 8 direction finders as described in Schulz [1997]. Fig. 1 shows the borders of Austria and the area of investigation. The average location accuracy in the area of investigation is assumed to be in the range of 600 m and the detection efficiency is assumed to be greater than 90%.

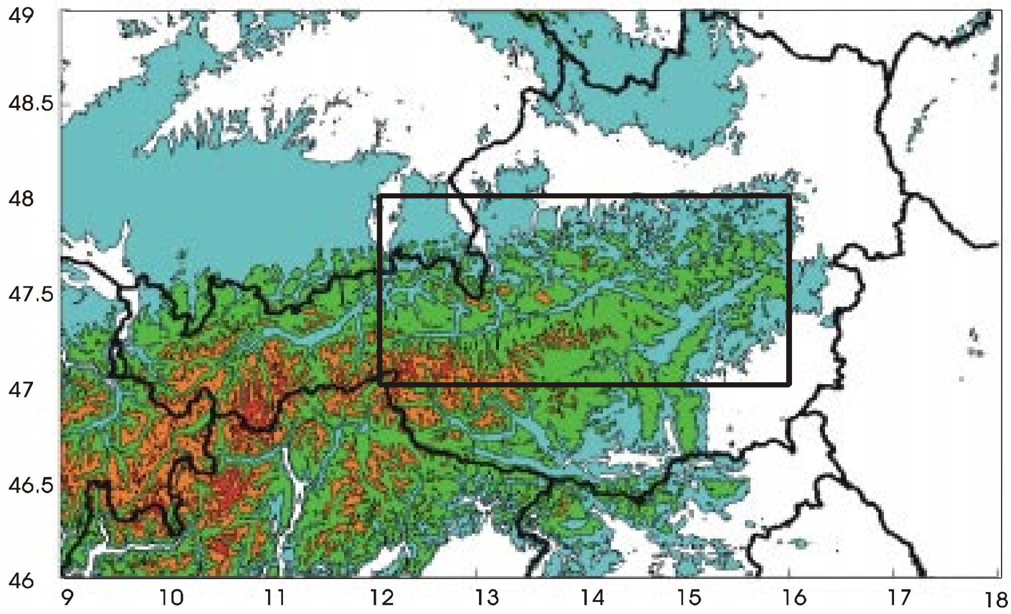

Fig. 1: Elevation plot for the area of investigation

Areas of white color in Fig.1 correspond to altitudes of less than 500m, blue areas to altitudes between 500m and 1000m, green areas to altitudes between 1000m and 2000m, orange areas to altitudes between 2000 and 2800m, and red areas correspond to altitudes above 2800m.

The area of investigation is shown as a rectangle in Fig. 1. The limits are 12° and 16° longitude and 47° and 48° latitude respectively. This area was chosen because it is in the center of the network, where we can assume the best performance of the network.

We divided the area of investigation into 57600 squares with an area of about 0.6 km^2. The altitude was divided in 100m segments. The number of squares of equal altitude is not evenly distributed over the area of investigation. Fig. 2 shows the distribution of the number of squares of the same altitude.

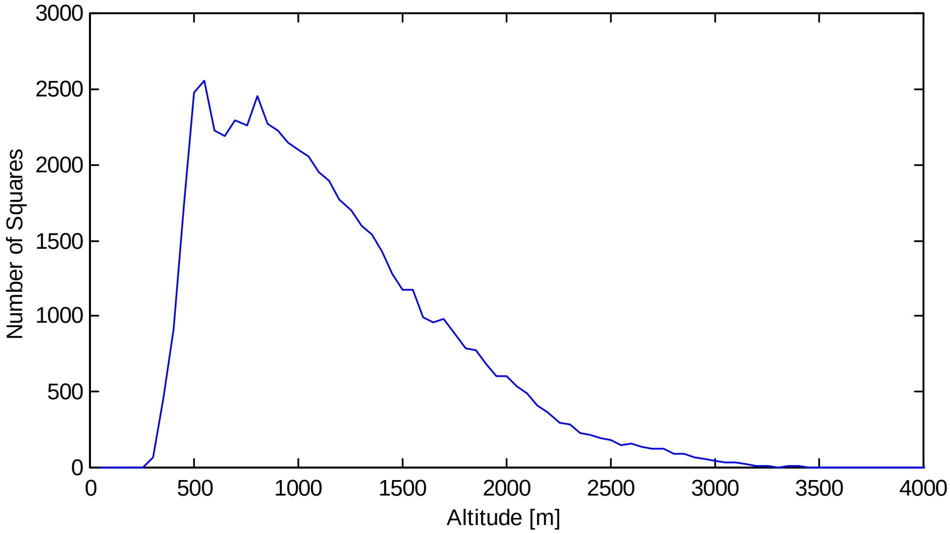

Fig. 2 : Number of squares of a given altitude in the area of investigation

N=200 squares at the 2500m segment means that in the area of investigation there are 200 squares with an altitude between 2500m and 2600m.

3. Results

Fig. 3 shows the total number of flashes used for this analysis for each altitude segment. Flashes were extracted from our lightning database for the time period from 1995 to 1998. From Fig. 3 we can see that for the altitude range from 2500m to 2600m the database contains about 500 flashes. For the altitude range from 500m to 2000m more than 3000 flashes were extracted from the lightning database.

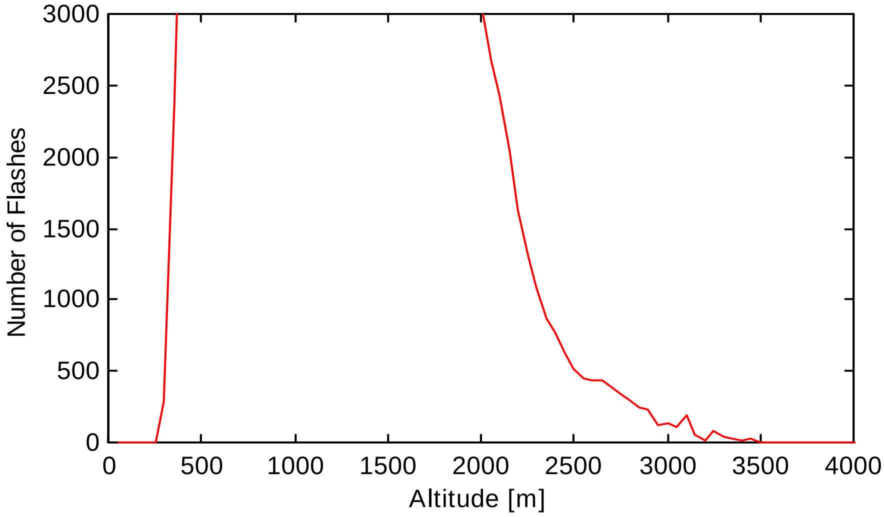

Fig. 3: Number of flashes versus altitude

Fig. 4 shows the mean lightning density (+) and the corresponding standard deviation

(o) versus altitude in the area of investigation. First we calculated the lightning density for each individual square. Then the mean lightning density for all squares of equal altitude range was determined.

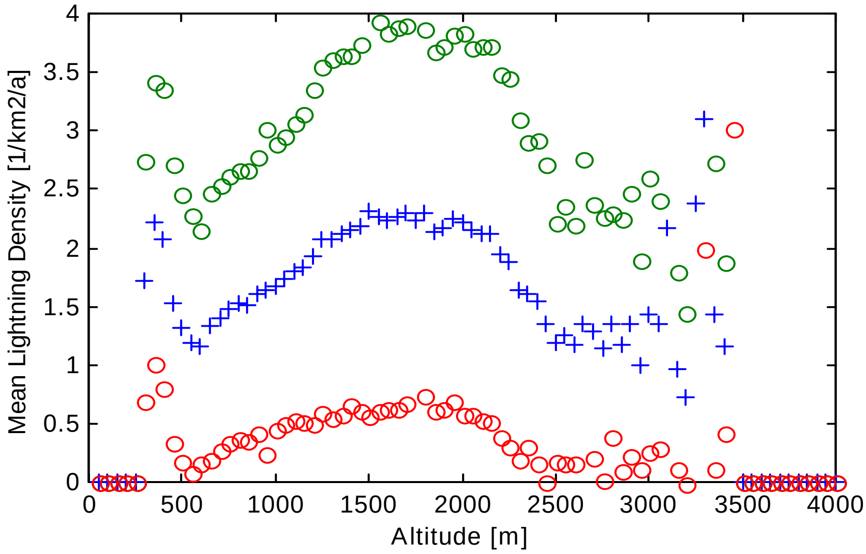

Fig. 4: Mean lightning density and standard deviation versus altitude

Fig. 4 shows an increase in flash density for altitudes ranging from 500m to 2000m. For altitudes above 2000m there is a rapid decrease of lightning density. For altitudes less than 500m we found a decrease of flash density with increasing altitude.

In Fig. 5 the mean peak currents as a function of altitude can be seen. Again all flashes in all segments at a certain altitude contributed to the mean peak current at this altitude range.

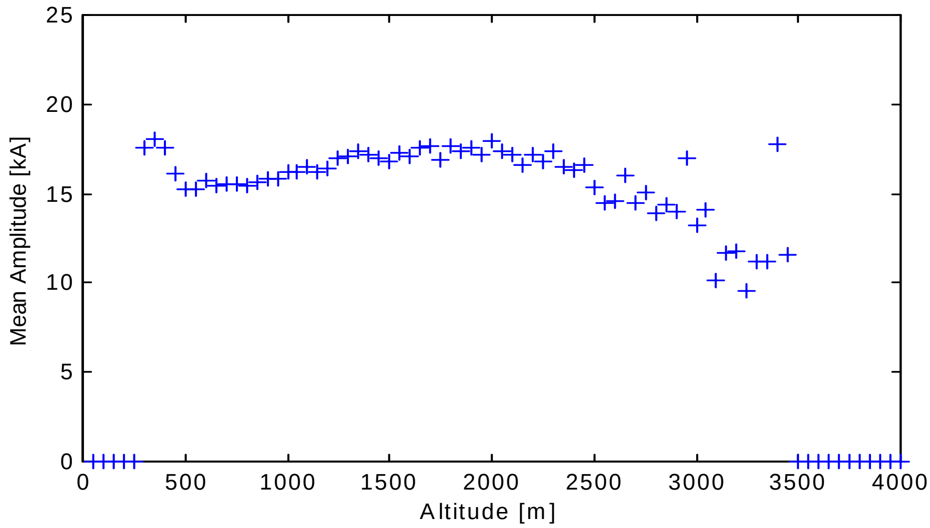

Fig. 5: Mean peak current versus altitude

This figure also shows that at an altitude of about 2000m there is a change in the characteristic. Up to altitudes of 2000m the mean amplitude is slightly increasing and starts decreasing at altitudes above 2000m.

4. Discussion

We have shown that the measured lightning flash density is decreasing for altitudes greater than about 2000m. Also the characteristic of the mean peak current versus altitude shows a change at an altitude of about 2000m. The change of the characteristic of lightning flash density and mean peak current at this altitude is probably due to the fact that very often regions with these high altitudes are inside or at least very close to the thunder storm clouds. We can speculate that at these altitudes either the field signatures of cloud to ground flashes are changed and therefore only some flashes are located or there is a real decrease of flash density and peak currents at high altitudes.

Due to the large area of investigation, meteorological aspects of thunderstorms in Austria are averaged. Nevertheless the climate has a significant influence on the absolute value of lightning density. The results in this study are therefore related to the meteorological situation in Austria and all determined values (e.g. lightning densities, altitudes where the characteristic changes, ...) are probably not valid for regions of different meteorological or climatic conditions but the overall characteristic should be the same.

5. References

Diendorfer G., Schulz W., Rakov V.: Lightning Characteristics Based on Data from the Austrian Lightning Locating System. IEEE-EMC Transactions, Vol.40, Number 4, Nov. 1998.

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