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LIGHTNING STATISTICS IN THE REGIONS OF SAENTIS AND ST.CHRISCHONA TOWERS IN SWITZERLAND

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Abstract - In this paper we present lightning statistics in the regions of the Säntis Tower and the St. Chrischona Tower in Switzerland. We analyze lightning data for an eight-year period from 1999 to 2006. This work is part of a recent study on overall lightning activity in Switzerland. Lightning location data from the EUCLID (European Cooperation of Lightning Detection) lightning location system (LLS) were used in the study.

The two telecommunications towers are situated in two distinct parts of the country, characterized by different geographical conditions. The Säntis Tower is 124 m tall and is located on the top of the Säntis Mountain (2505 m ASL) in the eastern Swiss Alps. The tower location exhibits the highest lightning flash density in Switzerland during the period from 1999 to 2006. The St. Chrischona Tower is 250 m tall and is located in a relatively flat region near Basel in the northern part of Switzerland (493 m ASL). Various regional maps and statistics around the two towers are presented, including number of flashes and strokes, number of strokes per flash (flash multiplicity), and peak current. The effect of each tower was analyzed by comparing lightning statistics within a defined range around the tower with those obtained on an external ring excluding the tower, as done previously for the analysis of the Gaisberg tower in Austria. The results indicate that the lightning incidence to the Säntis tower (about 100 times a year) is much higher than that to the St. Chrischona tower (less than 10). We found also a relatively high value of flash multiplicity for strikes detected in the Säntis tower region, implying that most of strikes to this tower are upward initiated flashes.

1 INTRODUCTION

Lightning Location Systems (LLS), which are widely used today, represent an important tool for the establishment of regional lightning statistics. These systems provide, besides the lightning discharge type and coordinates, estimates of lightning peak current and the number of strokes per flash.

LLS networks appeared commercially in the late 70's and were installed for the first time in Switzerland in 1989. All statistics presented in this paper are obtained from the lightning database of the EUCLID (European Cooperation of Lightning Detection) network. When lightning parameters are extracted from LLS, it is important to take into account the performance and limitations of the LLS network [1-4].

Analysis of the overall lightning activity in Switzerland [1] showed that the country's highest lightning activity region is situated south of the Alps (Tessin). This region exhibits one of the highest lightning activities in Europe. The analysis in [1] revealed also high lightning densities in some regions located around tall towers.

Figure 1 shows the Ground Flash Density (GFD) in Switzerland during the eight-year period from 1999 till 2006. We note a GFD of more than six Flashes ($km^{-2}.yr^{-1}$) in the southern part of Switzerland as well as in the immediate regions around the Säntis tower and the Die Rigi tower. In order to observe the effect of the tower on the local lightning activity, we have done a more detailed regional analysis around the Säntis tower and the St. Chrischona towers, which are situated in two different geographical areas, marked by a cross sign in the map.

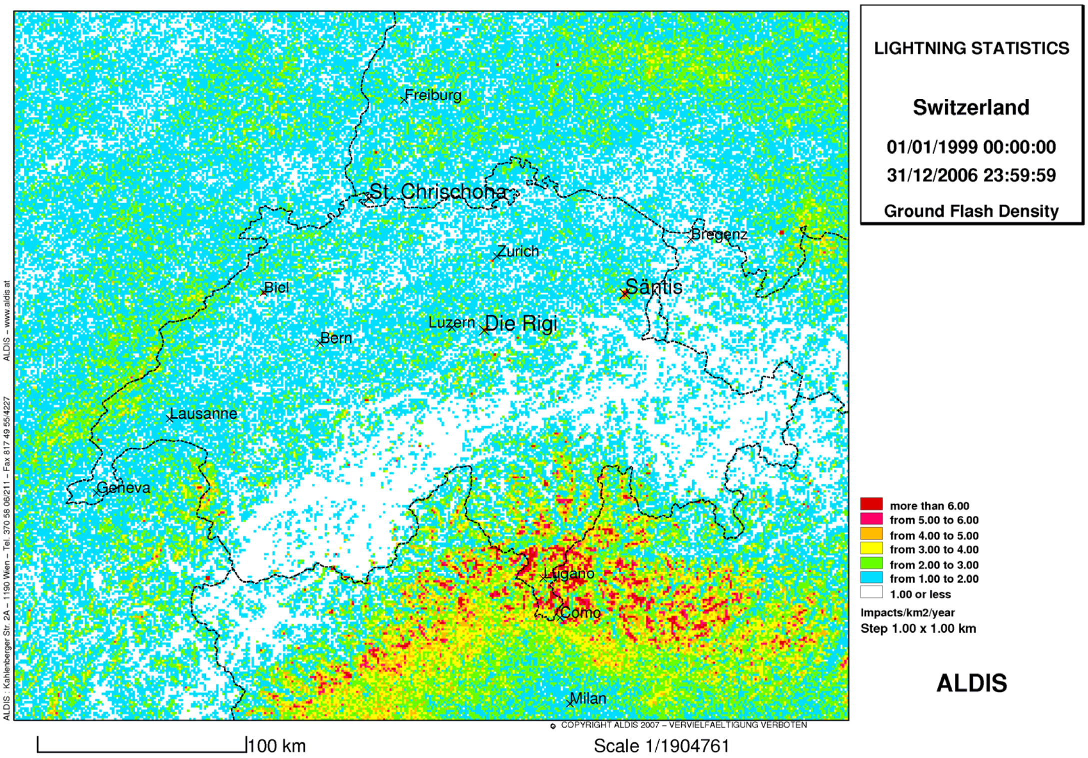

Fig. 1 - Lightning flash density (Flashes km^{-2} yr^{-1}) in Switzerland during 1999-2006.

The Säntis Tower is 124 m tall and it is located on the top of the Säntis Mountain (2505 m ASL) in the eastern Swiss Alps. The tower location exhibited the highest lightning flash density in Switzerland during the period from 1999 to 2006 and there are current plans to instrument this tower to obtain lightning current data. The St. Chrischona Tower is 250 m tall and it is located in a relatively flat region near Basel in the northern part of Switzerland (493 m ASL). This tower was instrumented in the 1990s by Montandon and Beyeler and lightning return stroke current records were obtained for several years [5, 6].

In order to better represent the lightning statistics around the towers, we have considered a 2x2 km^2 area around each tower and the analysis was performed using a 100x100 m^2 grid cell. Considering the fact that the real accuracy of the network depends on its physical characterization and not on software mapping resolution, we did not use a grid cell smaller than the network location accuracy. Additionally, to avoid having the grid cells representing artificially large flash densities (flashes.km^{-2}.yr^{-1}) around the towers, only the number of flashes was represented instead of the flash density.

The effect of each tower on the local lightning statistical data was analyzed by comparing lightning statistics within a 500-m radius circle around the tower with those obtained on an external ring centered on the tower, with inner and outer radii equal to 2 and 5 km, respectively. This same approach has already been adopted by Diendorfer and Schulz for the analysis of the Gaisberg tower in Austria [7]. The size of the ring was selected considering that in this region the average length of the semi-major-axis of the locating error ellipse of the LLS network is about 1.5 km [2]. It is worth noting that the area of the circle is about 84 times smaller than the area of the ring.

2 DETAILED STATISTICAL ANALYSIS OVER THE REGION OF THE SAENTIS TOWER

Figure 2 shows the spatial map of the total number of negative CG flashes around the Säntis tower. Although we have chosen a 2x2 km^2 region around the tower to represent the closest strikes to the tower, data gathered for generating other statistics (presented later) are based on larger geographic regions, for which the larger amount of data results in more reliable statistics. In Figure 2, one can see that the highest lightning activity is located in the immediate vicinity of the tower. This is indicative of the fact that most of the strikes actually hit the tower. As we can see on this spatial map, the number of flashes starts out from zero within a few hundred meters from the tower and increases continually toward the tower. Although it is supposed that most of these surrounding flashes struck the tower, the LLS network located them somewhere close to the tower.

On the other hand, Figure 2 shows a very high location accuracy of the LLS network in this region considering the fact that the hotspot of the number of flashes matches almost perfectly with the known exact location of the tower.

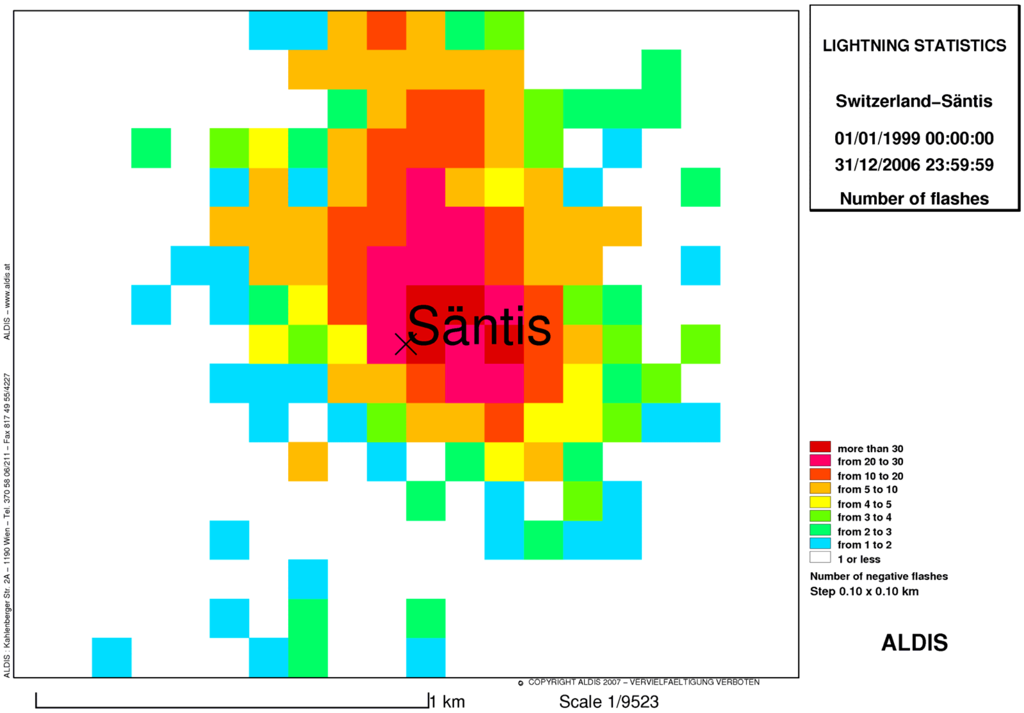

Fig. 2 - Total number of negative flashes around Säntis tower during 1999-2006.

Figure 3 compares the annual number of negative flashes within the 500-m radius circle around the tower and within the 2-5 km ring around the tower. The goal of such an analysis is to show the effect of the tower on the lightning activity in the region surrounding the tower.

It can be observed from Figure 3.a that the number of flashes within the circle is of the same order of magnitude as the number of flashes in the ring, even though, as mentioned before, the surface of the ring is about 84 times as large as that of the circle. This reflects the fact that the density of flashes to the tower and in its immediate vicinity is much larger than the density in the surrounding region. On the other hand, Figure 3.b, takes into account the total surface of circle and the ring and shows the total number of flashes per km^2 in each region. The data in this figure are obtained by dividing the total number of flashes occurring in each circle or ring region, by its corresponding surface. In Figure 3b, one can see that the number of negative flashes occurring in the immediate vicinity of the tower (within the circle) is about 100 times greater than the number of negative flashes within the ring. This highlights the enhancement effect of the tower initiating presumably a large number of upward lightning flashes.

It is also worth noting that the number of negative flashes within the circle exceeds 200 in 2000 and 2001, while in other years it ranges from 30 to 100. As we are analyzing a small region of the whole network, it is difficult to relate these changes to the global changes in the network configuration.

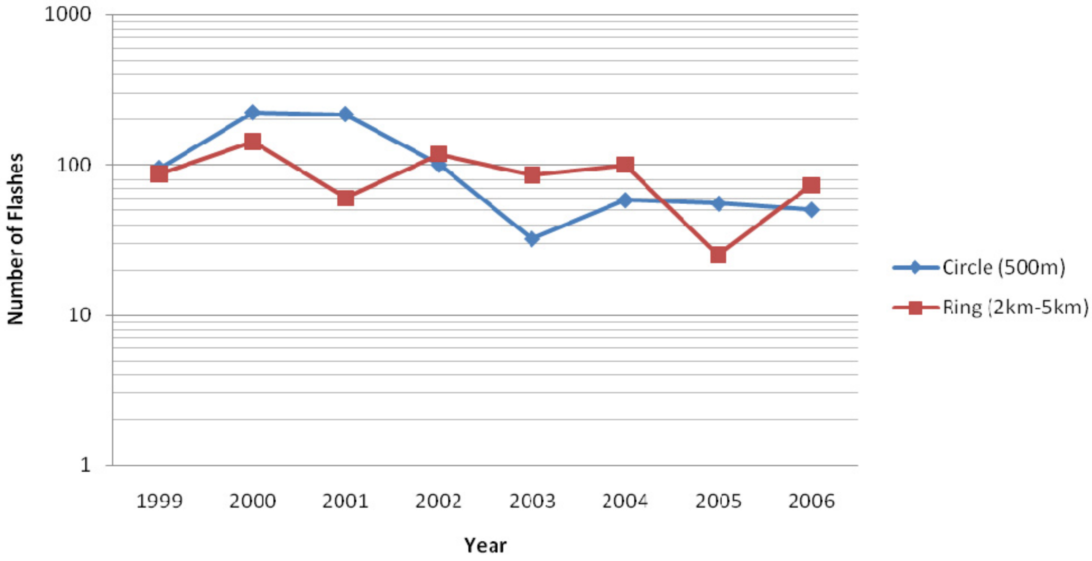

Fig. 3.a - Annual number of negative flashes within a circle with 500m radius and an external ring (2 km-5 km) around Säntis during 1999-2006.

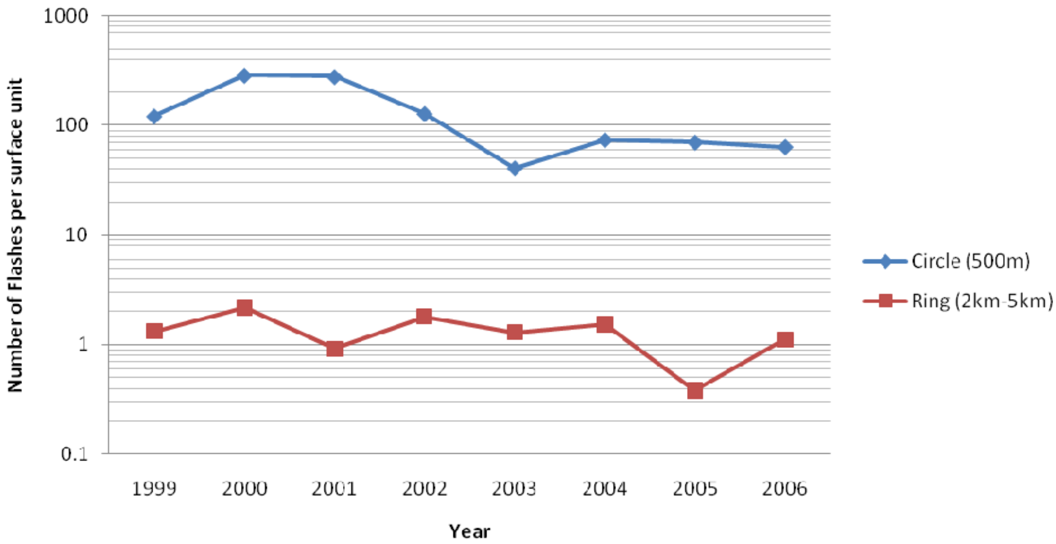

Fig. 3.b - Annual number of negative flashes per km^2 within a circle with 500m radius and an external ring (2 km-5 km) around Säntis during 1999-2006.

Table 1 summarizes lightning return-stroke parameters of negative flashes including the total number of flashes and strokes, the average flash multiplicity, and the estimated average and median flash peak current.

Table 1: Statistics of negative flashes and strokes around Säntis tower during 1999-2006.

	Total Number	Average Flash Multiplicity	Average peak current [kA]	50% peak current [kA]
Flashes (500m Circle)	832	3.4	16.2	14.2
Strokes (500m Circle)	3392	---	16.6	15.1
Flashes (2km-5km Ring)	691	2.3	15.4	11.5
Strokes (2km-5km Ring)	1461	---	14.7	11.6

The above mentioned parameters are shown for flashes and strokes within the two different regions, circle and ring. It should be noted that in Table 1, by flash peak current, we mean the peak current of the first stroke in each flash. Analyzing the same statistics for subsequent strokes gave similar results and it is not represented.

The following comments can be made on the results presented in Table 1:

1. The average flash multiplicity in the circle is about 50% higher than that in the ring. This latter is very similar to the value obtained in Austria [3]. This difference could be due to the fact that an important fraction of flashes within the circle are presumably upward flashes to the Säntis Tower, and that some α-component pulses [8] are identified as return strokes.
2. In the circle region, the average peak current for the first return stroke, 16.2 kA, is slightly smaller than the average peak for all strokes, 16.6 kA. This unexpected result could again be due to the fact that a significant number of flashes in the circle are of upward type for which α-component pulses could have been identified as a first stroke.

3 DETAILED STATISTICAL ANALYSIS OVER REGION OF ST. CHRISCHONA TOWER

An analysis similar to that of the Säntis tower presented in the previous section was performed for the St. Chrischona tower. Although St. Chrischona tower is almost twice as tall as the Säntis tower, it is not identified as a hot spot in the spatial map of ground flash density (GFD) in Switzerland, see Figure 1. We observe a moderate GFD for negative flashes that is between 1 and 2 impacts per year and per square kilometer.

Figure 4.a shows the total number of negative flashes occurred within 500 m distance from the St. Chrischona tower and within a 2-5 km ring around the tower. In Fig. 4.b, we present the same data by dividing the total number of flashes occurring in each circle or ring region, by its corresponding surface. Unlike the case of the Säntis tower, it can be seen that the number of negative flashes occurring within the circle is only about 2-10 times higher than the number of negative flashes within the ring. This value (2 to 10) is an indication of the number of strikes to the St. Chrischona tower and is in agreement with data reported by Montandon et al. [5, 6].

Table 2 shows various statistics of negative flashes occurred around the St. Chrischona tower during 1999-2006. As previously done for the Säntis tower, these statistics refer to negative flashes and strokes within a 500 m circular and a 2km-5km ring area around the St. Chrischona tower. The tabulated parameters include the total number of flashes/strokes, average flash multiplicity, average flash peak current and the 50% percentile (median).

It can be seen from Table 2 that the statistical data for the two regions (circle and ring) around the St. Chrischona tower exhibit less differences from one another compared to the data related to the Säntis tower. This is presumably due to the relatively low number of strikes to the St. Chrischona tower, which does not result in a dramatic change of the overall statistical data. The Säntis tower, although shorter in height than the St. Chrischona tower, is located on the top of a mountain. This results in an additional field enhancement which is accounted for through the concept of the effective height (e.g. [9, 10]). The effective height of the Säntis tower is expected to be significantly larger than that of the St. Chrischona tower.

The only appreciable difference between the two regions (circle and ring) around St. Chrischona tower is in the value for the average flash multiplicity. The value obtained for the ring, 1.9, is very similar to the average value for the overall Switzerland [1] and for neighboring Austria [3]. The unexpectedly low value for the circle region can be due to a limited number of events (27 flashes).

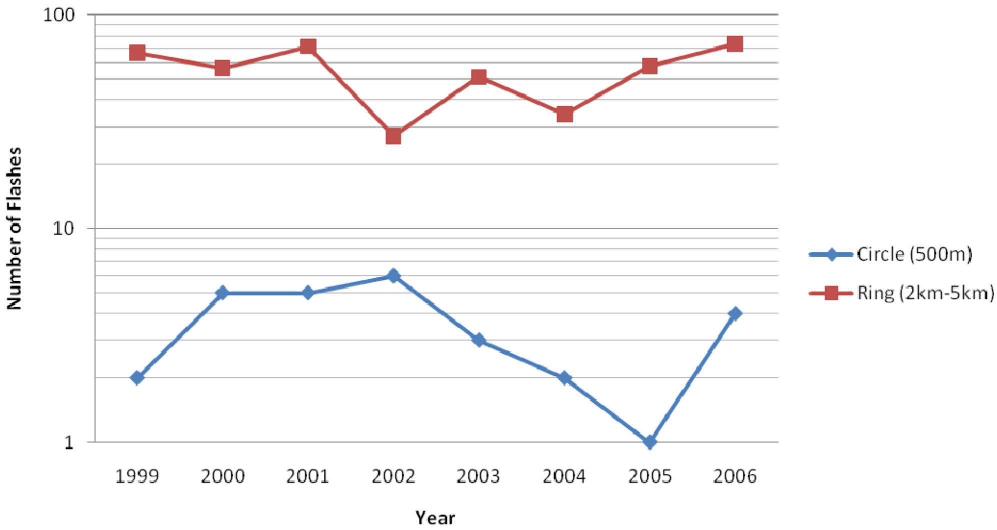

Fig. 4.a - Annual number of negative Flashes within a 500m distance and 2-5km ring around from St. Chrischona tower during 1999-2006.

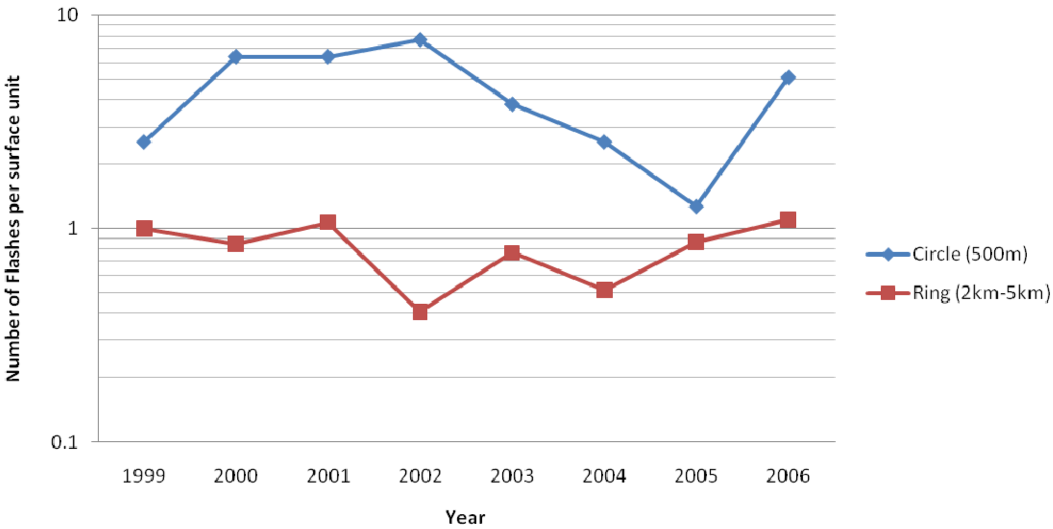

Fig. 4.b - Annual number of negative flashes per km^2 within a 500m distance and 2-5km ring around from St. Chrischona tower during 1999-2006.

Table 2: Statistics of negative flashes and strokes around St. Chrischona tower during 1999-2006.

	Total Number	Average Flash Multiplicity	Average peak current [kA]	50% peak current [kA]
Flashes (500m Circle)	27	1.4	18.5	14.2
Strokes (500m Circle)	45	---	16.2	12.7
Flashes (2km-5km Ring)	435	1.9	17.0	13.1
Strokes (2km-5km Ring)	775	---	16.2	12.9

4 SUMMARY AND CONCLUSION

Lightning statistics in the regions of the Säntis Tower and the St. Chrischona Tower in Switzerland were presented and discussed. The data were obtained from the EUCLID (European Cooperation of Lightning Detection) lightning location system (LLS) and were analyzed for an eight-year period from 1999 to 2006.

The two telecommunications towers are situated in two distinct parts of the country characterized by different geographical conditions. The Säntis Tower is 124 m tall and is located on the top of the Säntis Mountain (2505 m ASL) in the eastern Swiss Alps. The tower location had the highest lightning flash density in Switzerland for the complete whole 8-year period. The St. Chrischona Tower is 250 m tall and is located in a relatively flat region near Basel, near the border between Switzerland, France and Germany, in the northern part of Switzerland (493 m ASL). Various regional maps and statistics around the two towers were presented, including number of flashes and strokes, number of strokes per flash (flash multiplicity), and peak current. The effect of each tower was analyzed by comparing lightning statistics within a defined range around the tower with those obtained on an external ring excluding the tower. The results indicate that the lightning incidence to the Säntis tower (about 100 times a year) is much higher than that to the St. Chrischona tower (less than 10). We found also a relatively high value of flash multiplicity for flashes detected in the Säntis tower region, implying that most of strikes to this tower are upward initiated flashes.

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