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Comparison of Lightning Data Collected by Location Systems of Different Technology

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Abstract:
Different lightning location systems provided lightning data for the MAP database during the MAP SOP. In this paper we compare lightning data sets recorded during the MAP-SOP from two different lightning location systems, the so called SOP-lightning location system (SOP-LLS) and the lightning location system from the British Met. Office called ATD.
The SOP-LLS was designed [Dorninger, 1999] to provide the best detection efficiency (DE) over the entire alpine region that can be achieved with today's available technology for a large region like the Alps. Thus it was assumed that this system detects more flashes than the ATD system which covers a much larger area than the Alps and had, at the time, a low processing ability. We will show that this assumption was correct and we will determine the overall DE of the ATD system relative to the SOP-LLS. Comparison of the lightning peak current distributions of both systems indicates that the ATD system mainly detects flashes of higher peak currents.

1. Introduction:
Different lightning data sets for the MAP-SOP (7.9.1999 – 15.11.1999) are available at the MAP data center. These data sets are the output from different lightning location systems.

- A French network operated by Meteo France.
- A network operated by the British Met. Office called ATD (**A**rrival **T**ime **D**ifferences) and
- a joint network of the lightning location systems in France (Meteo France), Italy (CESI), Switzerland (SIEMENS), Germany (SIEMENS), Slovenia (EIMV) and Austria (ALDIS). The network is called SOP-LLS (**S**pecial **O**bservation **P**eriod **L**ightning **L**ocation **S**ystem) and was operated by ALDIS.

The lightning location technology used by the French network and the SOP-LLS is from the same manufacturer (Global Atmospheric Inc.). Thus performance differences of those two systems are only related to the different network configurations in terms of system setup parameters and geographical system coverage. The system of the British Met. Office called ATD (**A**rrival **T**ime **D**ifference) applies a completely different technology and operates also in a different frequency range.

Because the Meteo France system does not cover the entire alpine area with a uniform and high performance, only data from the SOP-LLS and the ATD system are used for comparison in this paper.

One of the most important performance parameters of lightning location systems is the so called detection efficiency (DE). Regarding the DE of a location system it is necessary to distinguish between different types of DE, the stroke, the flash, the absolute and the relative detection efficiency respectively. The flash detection efficiency is defined as the fraction of flashes detected from the total number of really occurring flashes. The stroke detection efficiency is defined the same way regarding the individual strokes. Rubinstein [1995] has shown that the relation between stroke and flash DE strongly depends on the distribution of the number of strokes per flash and that the flash DE of a location system can be appreciably higher than the stroke DE. Absolute DE is the ratio between the number of flashes (strokes) detected by the network and number of flashes (strokes) really occurring in nature. The relative DE is defined as the ratio between the number of flashes (strokes) detected by a network and the number of flashes (strokes) detected by another or even the same detection system.

In this paper we compare flashes detected by the ATD system relative to the SOP-LLS. Thus the DE we are speaking about is the relative flash DE where the output of the SOP-LLS is used as a reference of 100 %.

1.1 SOP-LLS

The SOP lightning location network was established by the interconnection of 29 sensors in the different countries as shown in Fig. 1.1. Some additional sensors in the Netherlands, in northern Germany, in Norway and in the central European countries which where also connected to the network are not shown in Fig. 1.1 because they are far away and do not contribute to lightning detection in the MAP region.

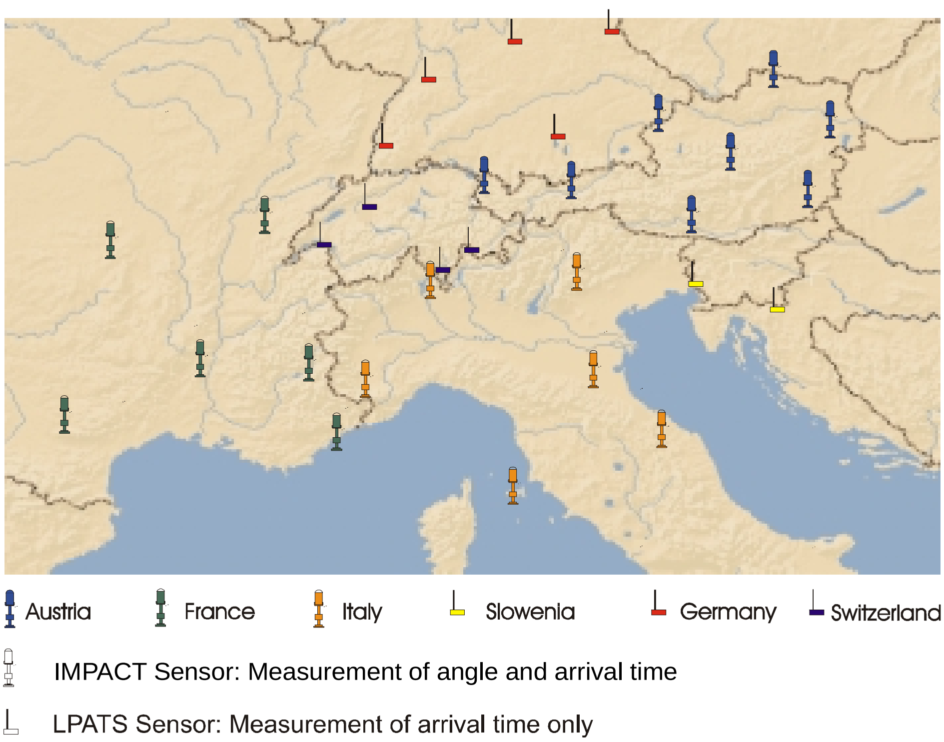

Fig. 1.1: SOP-LLS configuration

Two different types of sensors are installed. So called LPATS sensors that are only detecting the time of arrival of the lightning electromagnetic field and IMPACT sensors that are detecting the time of arrival of the lightning electromagnetic field and the angle of field incidence. The data of all sensors have been collected at the ALDIS control center in Vienna. Raw Sensor data from Italy, France and Slovenia were transferred utilizing the Internet whereas data from Germany and Switzerland were transferred over a leased line to the ALDIS control center. Inside Austria a X.25 network is used for the sensor communication.

All data processing was also performed at the ALDIS center. As a first step the applied location algorithm (LP2000) groups together sensor messages belonging to the same stroke based on their time stamps. In the next step a stroke location is calculated for each group of data and in the final step the system groups together strokes attributed to the same flash. To the end user and also to the MAP database only flash information with the corresponding multiplicity (number of strokes in the flash) is provided. Besides time and location information the system also provides information about the current amplitude of the flash and whether the flash was a cloud to ground (CG) or a cloud to cloud (CC) discharge. Because only LPATS sensors report CC lightning only a very small fraction of all the CC lightning is detected by the MAP lightning location network. A more comprehensive description of the applied lightning location technology, is published in Schulz [1997].

1.2 ATD

The ATD system is a network of 7 sensors (see Fig. 1.2) which utilizes the time of arrival differences of the electric field signal of lightning return strokes at the individual sensors. It determines the arrival time difference of the entire waveform by correlating in time the digitized waveform received at one station with that received at a standard station. The stroke location is obtained by a hyperbolic intersection technique based on spherical earth geometry. Four stations are required to provide a location. The location accuracy is dependent on different parameters, mainly the timing accuracy, the number of stations contributing waveforms and the geometry of the flash location in relation to the positions of the contributing stations. The timing accuracy is typically 25 μs and with ideal geometry this gives a location accuracy of about 5 km. As the Alps are at the center of the ATD network it is expected that the geometry is favorable, but if one or both of the Mediterranean stations are not functioning fully, the accuracy will consequently get worse.

Fig. 1.2: ATD network configuration

The system was designed to cover an area of up to several thousands of kilometers. Only vertical field signals in the VLF band propagate these long distances within the earth-ionosphere waveguide. Thus the system operates in the frequency range of 10kHz. Currently the ATD system does not discriminate between cloud to cloud (CC) or cloud to ground (CG) signals though this additional information is planned to be implemented over the British Isles region in the near future. Due to processing constraints the gain of the system is set quite low resulting in the acceptance of only strong signals. Therefore mainly CG flashes are detected. Also, it must be noted that when there is strong activity over the British Isles, the performance of the system outside of this area suffers. This processing limitation should be relieved on completion of a major upgrade during 2000. More detailed descriptions of the ATD system can be found in Lee [1986], Lee[1989].

2. DE Comparison

To be able to derive a representative relative DE for the ATD system it is necessary to compare the data in areas where the lightning location system used as a reference has a high and uniform performance. Thus we selected for this comparison two distinct areas shown in Fig. 2.1 covering the alpine region. The geographical limits of both areas are given in Table 1.

Fig. 2.1: MAP region divided into two areas of investigation

Table 1: Limits of the two areas

	Longitude [°]	Latitude [°]
Area 1	10 - 17	46 - 49
Area 2	5 - 10	43.5 - 48

Due to a problem at the processing center of the British Met. Office the archiving of the data was not done on the 26.9.1999 and only incomplete data sets were stored on the 25.9.1999 and the 27.9.1999. Thus these 3 days were not taken into account in all the following statistics. The numbers of flashes detected by the SOP-LLS during these three days are given in Table 2.

Table 2: Number of flashes detected by the SOP-LLS during days of the ATD problems

	Area 1	Area 2
19990925	11	722
19990926	522	1090
19990927	27	463

In the following section all the detection efficiencies (DE) of the ATD system are relative to the SOP-LLS. For this comparison we took all flashes detected by the ATD system inside the two areas and searched for corresponding events in the SOP-LLS database without any geographical limitation. The reason for this is that the limited location accuracy of both systems would otherwise influence the result of the DE analysis. We defined a correlating flash as an event where we found a stroke in our database with a time difference of less than 1 second. The median of the absolute values of the time differences was 9 ms for both areas. For both areas an overall relative DE for the complete MAP-SOP of 21 % was found.

Table 3: Overall results

	Area 1	Area 2
Flashes detected by ATD	2914	9242
Mean relative ATD DE [%]	21	21
Mean relative ATD DE for neg. flashes [%]	17	17
Mean relative ATD DE for pos. flashes [%]	28	29
Mean absolute time difference [ms]	21	22
Median Distance [km]	3.6	3.9
Not detected by SOP-LLS	172 (6%)	476 (5%)

There are also some flashes located from the ATD system inside the area of investigation which are not detected by the SOP-LLS. About 6% (5%) of the flashes in area 1 (area 2) are not detected (see Table 3).On further investigation of these supposedly 'rogue' ATD flashes, it was found that their detection parameters were no different from those of the flashes that were detected by both systems, i.e. nothing would suggest that these rogue flashes were located incorrectly by the ATD system. They were all quite near in space and time to other flashes that were detected by both ATD and the SOP-LLS. It is true that the ATD system occasionally makes spurious fixes, but this is estimated as being as low as 0.004% of all flashes detected. A possible explanation would be that these rogues were strong C-C flashes that were not picked up by the SOP-LLS.

The location accuracy of the correlated ATD flashes is surprisingly high and almost the same in both areas.

In Fig. 2.2 and Fig. 2.3 only days when the SOP-LLS detected more than 10 flashes in one of the two areas were taken into account. For each individual day the number of flashes detected by the SOP-LLS is given on the top of each bin.

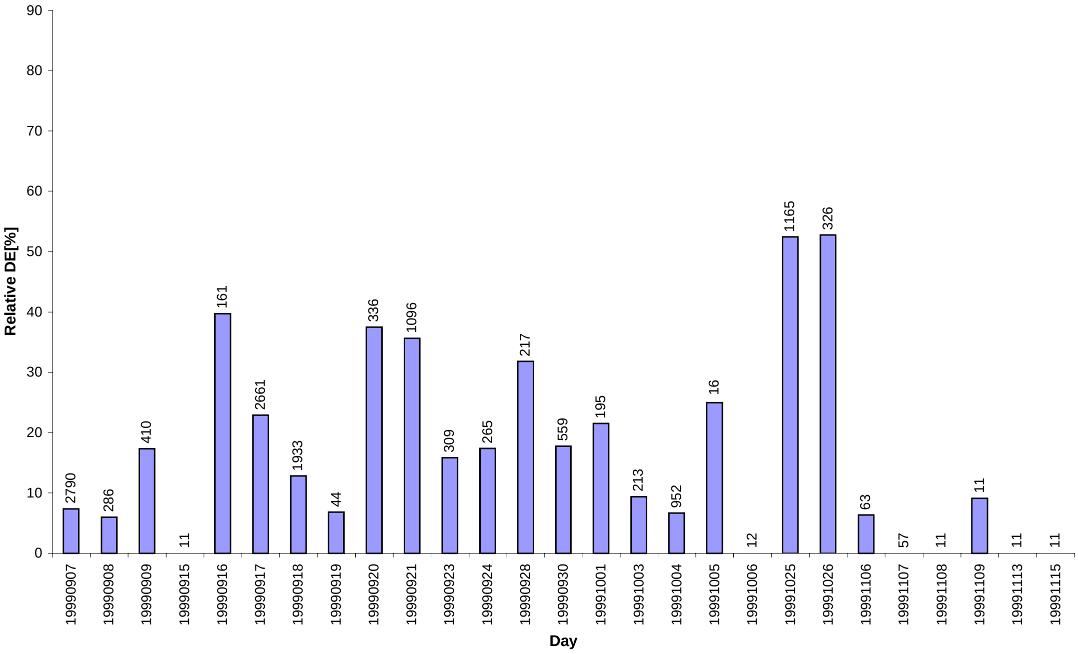

Fig. 2.2: Relative DE for area 1 on a day by day base

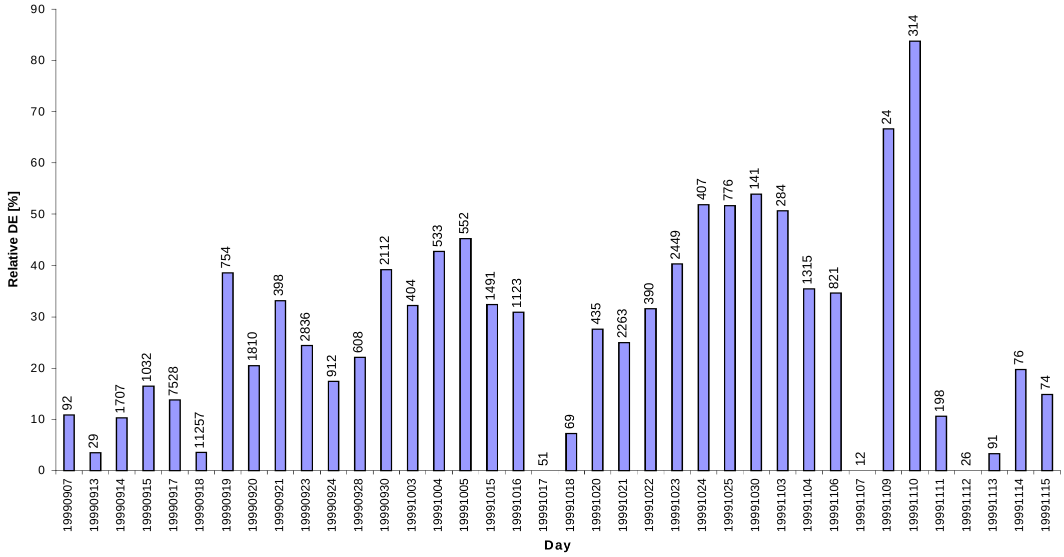

Fig. 2.3: Relative DE for area 2 on a day by day base

It can be seen from Fig. 2.2 and Fig. 2.3 that the DE of the ATD system varies significantly over different days. This is possibly caused by the ATD system being 'busy' detecting other strong thunderstorms in other areas.

3. Amplitude comparison

We also want to show which range of amplitudes are mainly detected by the ATD system. Therefore we computed in Table 4 the mean and the median values of the amplitude distributions for negative and positive flashes detected by each network in both areas.

Table 4: Mean and median peak currents

	Median neg. Flashes [kA]	Mean neg. Flashes [kA]	Median pos. Flashes [kA]	Mean pos. Flashes [kA]
Area 1 (ATD)	24	29	31	38
Area 1 (SOP-LLS)	13	17	17	25
Area 2 (ATD)	32	36	38	45
Area 2 (SOP-LLS)	19	23	24	32

Table 4 shows that mean and median values for the ATD system are always higher than the corresponding values for the SOP-LLS. This indicates that the ATD system mostly misses flashes of small current amplitudes and explains also the result that the DE for positive flashes is greater than for negative flashes because on average positive flashes have higher amplitudes than negative flashes.

4. Summary:

The data comparison confirmed our initial assumption that the performance of the ATD system in the MAP area is not as efficient as the performance of the SOP-LLS. The overall DE of the ATD system relative to the SOP-LLS is about 21%. We also showed that the ATD system mainly detects flashes with higher current amplitudes.
A relatively surprising result was the high accuracy of the flash locations calculated by the ATD system. Although the ATD system has very large baselines compared to the SOP-LLS the median distance between corresponding flash locations was about 4 km.

Of course the results of this comparison are only valid for the MAP region. The ATD system has a much better performance in the region of Britain because of the greater number of sensors. Currently the ATD system is undergoing an upgrade process to increase the processing capabilities which will of course increase also the performance of the system outside Britain.

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