COMPARISON BETWEEN REAL CG FLASHES AND CG FLASHES DETECTED BY A LIGHTNING DETECTION NETWORK

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Abstract

It is well known that a lightning detection network is able to record lightning activity. Among such networks, those using IMPACT technology are supposed to detect about 90 to 95% of cloud-to-ground flashes with peak current greater than 15 kA, with an average location accuracy of 500 m. One important question is to understand why some of the flashes are apparently not detected and to make clear how does the network groups into flashes the detected and located strokes.

A long duration thunderstorm has been studied by means of video photography and results are compared to data collected by the French detection and location network, the so called « Météorage network». This will allow us to evaluate what is the flash detection efficiency of the network and what are the limitations of direct observations.

In practice, every cloud-to-ground flash has been detected by at least one sensor. However, as we need at least two sensors to compute the flash location, such CG flash are not taken into account in data provided by the network. Moreover, data exhibits CG flashes with multiple polarity restrikes and sometimes the same observed CG flash appears several times in data. At last, it appears that some CG flashes are detected by a very large number of sensors although their peak intensity are lower than 30 kA. It is one of the goals of the present paper to deal with these observations.

Discussion about the total flash duration as compared with apparently observed flash lifetime will be opened. In some rare cases, estimation of the lightning location accuracy will be given.

Introduction

It is well known that a lightning detection network is able to record lightning activity. Among such networks, those using IMPACT technology are supposed to detect about 90 to 95% of ground flashes with peak current greater than 15 kA, with an average location accuracy of 500 m [**1998, Idone**]. One important question is to understand why some of the flashes are apparently not detected and to make clear how does the network groups into flashes the detected and located strokes.

A long duration thunderstorm has been studied by means of video photography and results are compared to data collected by the French detection and location network, the so called « Météorage network». This will allow us to evaluate what is the flash detection efficiency of the network and what are the limitations of direct observations.

Observations of Les Mées Thunderstorm

A V-shaped thunderstorm formed on South East France on September 19th 2000. This thunderstorm lasted for more than ten hours, but only its last three hours have been observed close to the village of Les Mées by an Observer (located at N 44°01.061' and E 06°00.850) who took still and video pictures during its main activity part (one hour), approximately between 23:00 and 24:00 UT. After processing video frames individually, it has been possible to compare observed lightning strikes to ground with data collected by the French National Network "Météorage". This network is composed of 18 IMPACT sensors, the data of which is analysed by the central computer of Météorage Company in Pau. Lightning flashes occurred at distances from several to fifty kilometres from the Observer. Due to the distance from the flashes to the Observer, thunder time-of-arrival data was not available.
Figures 1 and 2 exhibit two kinds of records of the storm performed by Météorage, the first giving a general view of the storm, the second giving a detailed map in Les Mées region.

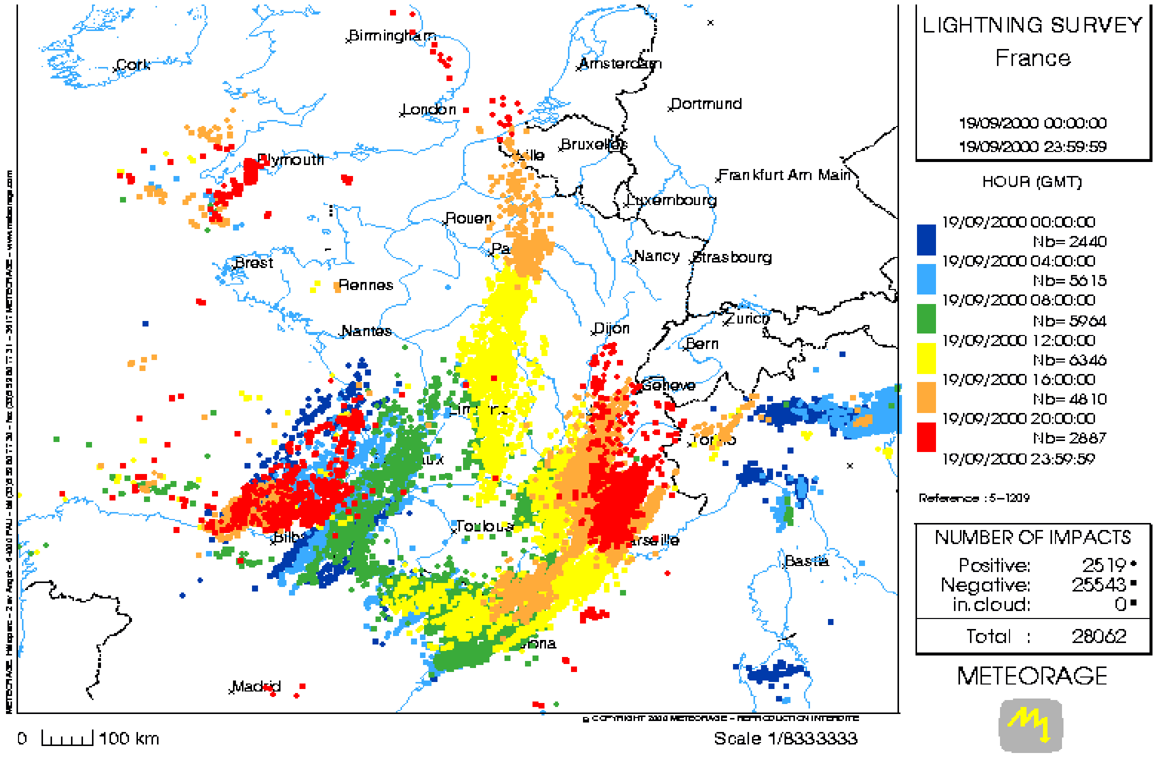


Figure 1 : Météorage Thunderstorm map at Les Mées (red)

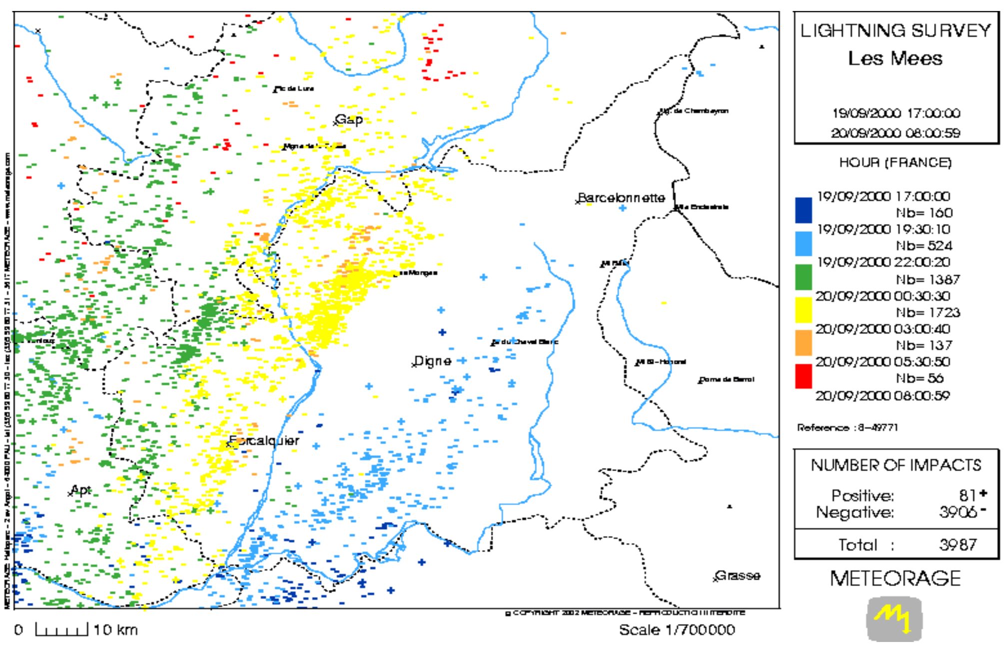


Figure 2 : Météorage Thunderstorm map at Les Mées (green)

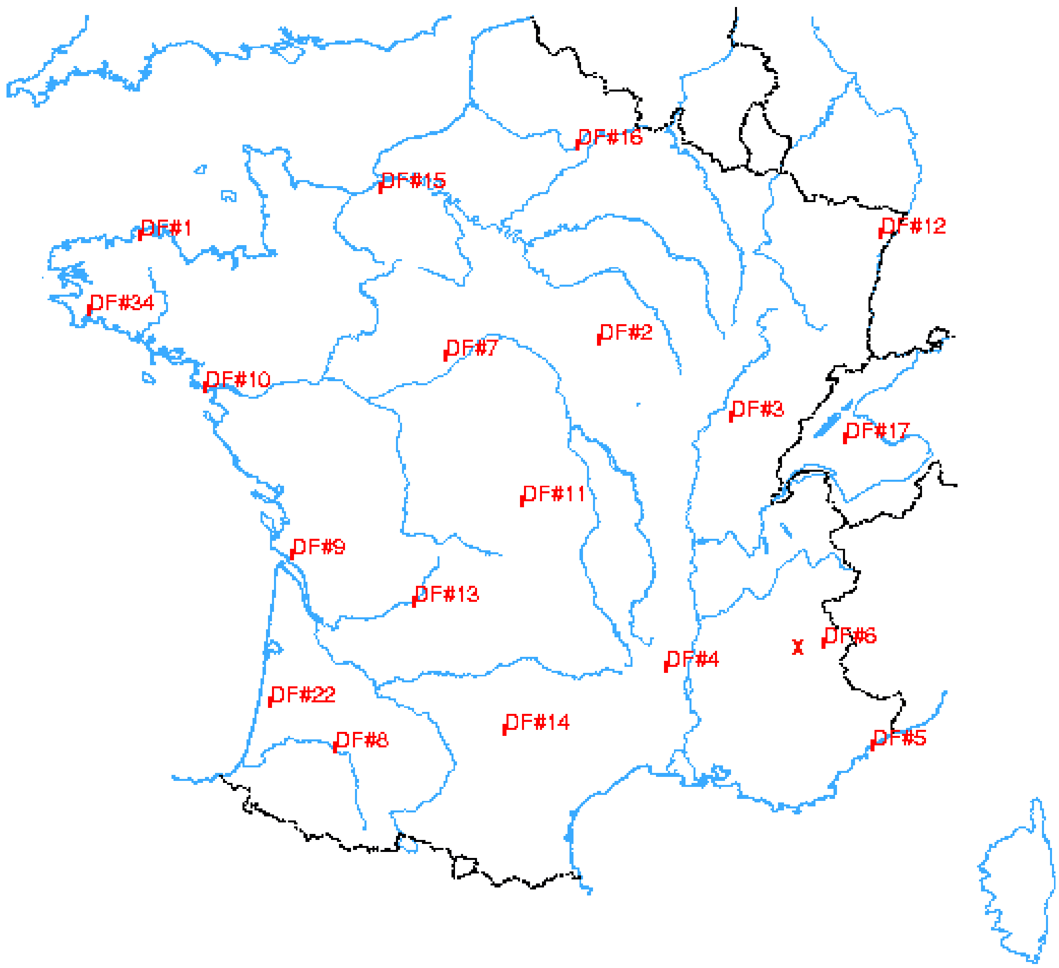


Figure 3 : IMPACT sensors map and Observer's location (X)

The three closest sensors are located in Aubenas (DF#4, N 44.54°;E 4.37°), Nice (DF#5, N 43.66°;E 7.21°) and Mont Dauphin (DF#6, N 44.67°;E 6.62°). They are respectively at 143 km, 105 km and 89 km from the Observer. We will show farther that DF#6 has been always involved in lightning detection whatever the lightning current intensity.
For each lightning event (observed flash to ground, estimated group of strokes from the network), we will compare the timing of event, the duration of the flash (flash duration computed by the network, number of video frames when available).

Comparison of observed and detected events

230 events have been observed and reported from the video data. Before any comment to the results, we have to report that such a comparison is not straightforward, because during the storm, some parts of the scenery are obscured by rain, so, sometimes the Observer is not able to discriminate every flash from some IC flashes (low thundercloud bottoms). He can only report long duration luminous activity. Most of the time, they are ground flashes. About 17 events have been found from the video frames which seemed not having been located by the network. However, we found for most of cases (12 of 17) that it was detected by the closest sensor DF#6. The remaining 5 flashes were probably misinterpretation of the video (low altitude IC flash inside rain). Hence, the balance is 225 real flashes to ground (230-5) and 213 flashes detected by the network (225-12), leading to a flash detection efficiency of about 95% (213/225 x 100). So, the first important result is that every flash to ground recorded by the Observer has either been detected (by sensor DF#6) or located by the network. It shows also that direct observations and network records have to be compared together for a perfect discrimination analysis of all flashes to ground. If a given flash is only detected by one single sensor, this flash is not located, so does not appear in the data listing. The reason why such a flash may be detected only by one sensor is not obvious and still remains to explain.

The following tables 1 and 2 show the comparison between observations and network data, after having dealt with the peculiar flashes reported just above. Two orientations of the video camera have been performed, due to the thunderstorm location with respect to the Observer, namely Ganagobie (table 1) and Les Mées village (table 2).

Among the 213 located flashes, 200 are of negative polarity (13 of positive polarity). The average negative flash current is 32.3 kA. The average positive flash current is 16.2 kA. The average numbers of strokes are respectively 3.35 and 1.5. Figure 5 displays the statistical distribution of first RS intensities. Let us notice that real flashes the intensity of which is lower than 10 kA are probably including the 12 flashes not detected by the network.

Figure 4 : Thunderstorm at Les Mées in a mountainous region of South East France

Each table exhibits several set of parameters characterising flashes to ground. First column shows the flash timing. Then appear the computed location of impact, polarity and first RS current intensity in kA, number of arcs, distance and azimuth from the Observer, number of identified flashes from the network and from video elaboration, and at last the number of sensors involved in the determination of the flash location. When one single sensor has detected a flash, there is of course no computed location for such a flash. Some of the strokes have been grouped together to assess a flash (see SAME and IDEM in tables), but it appears that this notion of a flash is more or less subjective and comparison between observations and detections lead to the conclusion that it is more accurate to use detected data in terms of strokes (or arcs) rather than in terms of flash. Hence, it is not pertinent to compare the number of flashes of the eight and ninth columns. Only, the number of detected strokes is meaningful.

Another comment is that a flash often is not composed of a single channel, but of several separate channels [**2002,Valine and Krider**], [**2000, Hermant**], [**1996, Berger**], [**1984, Thomson**] . We will come back later about such multiple channel flashes. In brief, the same flash may reach the ground in more than one location, often because several channels distant of several km may be attributed to one flash, with a common root at higher altitude.

An interesting information can be obtained in comparing the flash intensity with the number of sensors involved in its location. Figure 6 shows some correlation between those parameters.

Time	Latitude	Longitude	Current	Arcs	Distance	Azimuth	Mét. flashes	Obs. flashes	Sensors

22:59:24	44,4405	6,0101	-9,3	2	45,8	3	1	1	3
22:59:26	44,0505	5,7023	-42,2	3	21,9	276	1	1	11
22:59:27	44,0553	5,8082	-29,5	1	13,6	282	1	1	13
22:59:27	43,9149	5,6377	-18	1	29,8	244	1	1	6
23:00:12	44,4288	6,0112	-13,5	1	44,5	3	1	1	4
23:00:17	44,4322	6,077	-16,4	1	45,5	10	1	1	4
23:00:32	44,0856	5,6994	-108,6	1	22,8	286	1	1	9
23:00:32	44,0917	5,678	-17,1	2	24,7	286	SAME	IDEM	5
23:00:33	44,2018	5,8326	-46,4	1	22,3	329	1	1	14
23:00:48	43,8713	5,6299	-158,1	3	32,7	237	1	1	5
23:00:59	44,4387	6,1358	-13,2	1	47,3	15	1	1	2
23:01:01	44,4274	6,125	-8,6	1	45,8	15	SAME	IDEM	2
23:01:08	43,8704	5,6539	-103,2	1	31,1	235	1	1	14
23:01:42	43,8357	5,7026	-28,3	5	30,6	225	1	1	7
23:01:43	43,9236	5,7752	16,4	1	19,8	233	1	1	3
23:03:04	43,8471	5,6826	-65,2	7	30,9	229	1	1	10
23:03:29	44,1915	5,8542	34,4	1	20,4	332	1	1	6
23:03:29	44,2108	5,88	-11,5	2	21,5	339	1	1	3
23:03:30	44,4133	6,0963	-16,1	1	43,8	12	1	1	2
23:04:03	43,855	5,725	-173,2	5	27,8	225	1	1	8
23:04:05	44,4518	6,0435	-16,2	1	47,3	6	1	1	3
23:04:30	43,7412	5,5545	-45,1	2	46,4	226	1	1	10
23:04:45	44,3835	5,9549	-7,7	1	39,4	357	1	1	2
23:05:04	43,8714	5,7271	-74,7	4	26,4	228	1	1	5
23:05:04	43,9041	5,5686	20,7	1	35,3	246	1	1	2
23:05:32	43,8743	5,7455	-55,7	1	25,1	226	1	1	13
23:06:06	44,0169	5,656	-181,1	1	25,5	267	1	1	2
23:06:06	43,9387	5,7902	-19,7	2	17,8	235	1	1	7
23:06:07	43,9209	5,7782	-13,9	1	19,8	232	SAME	IDEM	3
23:06:42	44,0997	5,7608	-54,9	4	18,8	294	1	1	9
23:07:30	44,2878	5,749	-51,8	1	33,9	328	1	1	15
23:07:31	44,2354	5,7954	-13,5	1	27	328	1	1	2
23:07:58	43,9157	5,768	-13,2	2	20,8	232	1	1	3
23:07:59	43,91	5,7462	-20,3	2	22,5	234	SAME	IDEM	8
23:09:10	43,8891	5,6064	-18,6	3	33,3	242	1	1	2
23:09:11	43,992	5,7525	-8	2	18,2	256	1	1	2
23:09:26	44,0751	5,8431	-65,3	2	11,7	296	1	1	14
23:09:55	43,924	5,7018	-55,9	1	24,7	241	1	1	13
23:09:56	43,9312	5,6971	-19,1	1	24,7	243	SAME	IDEM	5
23:10:02	44,4405	6,0814	-7,2	1	46,5	10	1	1	2
23:10:19	44,0623	5,6877	-10,7	2	23,2	279	1	1	3
23:10:20	44,021	5,7674	-18,6	1	16,6	266	1	1	7
23:10:31	44,3961	5,8495	-24,7	1	42	346	1	1	9
23:11:04	43,9849	5,8353	-25,9	3	12,1	246	1	1	10
23:11:32	43,8128	5,6257	-36,5	2	36,8	229	1	1	10
23:11:33	43,7967	5,6633	-13,6	1	35,9	224	SAME	IDEM	5
23:11:54	43,9763	5,8349	-64,3	4	12,6	242	1	1	16
23:11:54	44,0105	5,9661	-3,8	1	2,2	197	1	1	2
23:12:48	44,1106	5,7038	-50,4	7	23,4	292	1	1	10
23:12:49	43,9933	5,7103	-13,4	1	21,5	259	1	1	3
23:13:38	43,9111	5,7701	-55,2	9	20,9	231	1	1	7
23:13:39	43,8944	5,7159	-16,7	1	25,5	234	SAME	IDEM	4
23:14:18	43,9171	5,8114	-120,3	5	18	226	1	1	2
23:14:31	44,3983	5,8408	-9,8	1	42,4	345	1	1	3
23:15:18	43,8766	5,6738	-10,6	5	29,4	234	1	1	5

23:15:19	43,8366	5,6747	-20,2	2	32,1	228	SAME	IDEM	5
23:15:33	43,9449	5,7871	-20,3	1	17,7	238	1	1	5
23:16:04	44,2397	5,8227	-15,3	1	26,3	332	1	1	5
23:16:29	43,9499	5,7757	-132,2	8	18,2	241	1	1	9
23:16:42	44,1912	5,8012	-12,2	1	22,7	322	1	1	3
23:17:02	43,9244	5,7557	-107,4	4	21	236	1	1	8
23:17:27	43,9528	5,7454	-69	3	20,2	245	1	1	7
23:17:44	43,9171	5,7439	-8,3	5	22,2	236	1	2	3
23:17:45	43,924	5,7459	-15,6	1	21,7	237	SAME	IDEM	7
23:17:51	44,2321	5,8617	-43,5	3	24,3	338	1	1	12
23:17:52	44,2232	5,8478	-16,8	1	23,8	334	SAME	IDEM	3
23:18:00	44,1346	5,8728	-50,6	3	14,2	325	1	1	12
23:18:02	43,9344	5,7414	-19	3	21,4	240	1	1	7
23:18:23	44,1975	5,8224	-79,6	2	22,3	327	1	1	15
23:18:26	43,979	5,7456	-8,8	1	19,1	253	1	1	3
23:18:27	43,9812	5,7465	-15,4	1	19	253	SAME	IDEM	3
23:18:58	44,0352	5,8545	-81,5	1	9,6	274	1	1	14
23:19:13	44,2816	5,7709	-13,3	1	32,4	330	1	1	2
23:19:32	44,1384	5,8348	-53,4	5	16,5	317	1	1	15
23:19:58	44,2046	5,848	16,8	1	21,9	332	1	1	2
23:20:22	44,2161	5,8426	-37,4	6	23,3	333	1	1	13
23:20:26	43,9611	5,6442	-9,3	1	27,4	254	1	1	2
23:20:51	43,9849	5,7627	9,6	1	17,6	253	1	1	3
23:21:01	44,2652	5,8797	-53,2	4	27,3	343	1	1	12
23:21:01	43,9705	5,3622	-27,5	1	49,4	262	1	1	2
23:21:26	44,0233	5,7847	-10,1	1	15,2	267	1	1	4
23:21:55	44,2841	5,8688	-48	1	29,5	343	1	1	15
23:22:00	43,9508	5,787	-41,9	5	17,3	239	1	1	10
23:22:01	43,9512	5,7793	-25,7	5	20,1	237	SAME	IDEM	12
23:22:17	43,9008	5,7236	-12,8	5	24,6	234	1	1	2
23:23:07	44,0091	5,7821	-104,4	3	15,5	261	1	1	12
23:23:07	44,0429	5,7992	-20,4	1	14,1	276	SAME	IDEM	10
23:23:09	44,2098	5,8154	-76,6	2	23,7	327	1	1	6
23:23:10	44,2062	5,8506	-11,5	1	22	333	SAME	IDEM	2
23:23:24	43,9193	5,7432	-19,3	4	22,1	236	1	1	7
23:23:33	44,2345	5,8273	-18,1	2	25,7	332	1	1	6
23:23:34	44,241	5,8647	-14,8	1	25,1	339	SAME	IDEM	6
23:24:00	44,2145	5,8541	-30,1	2	22,7	335	1	1	11
23:24:32	44,1767	5,8302	-14,5	2	20	325	1	1	2
23:25:03	44,2256	5,8518	-79,3	4	23,9	335	1	1	12
23:25:17	44,0001	5,7745	-23,5	1	16,3	258	1	1	12
23:25:17	44,1801	5,5009	-21,9	1	41,3	294	1	1	2
23:25:18	44,0019	5,7742	-29,2	2	16,3	259	1	1	9
23:25:38	44,0301	5,8705	-21,8	1	8,3	270	1	1	14
23:26:02	44,2369	5,8672	-67,1	10	24,6	339	1	1	6
23:26:22	43,9389	5,7312	-14,4	4	21,9	242	1	1	3
23:27:28	44,2013	5,8943	-26,7	2	20,2	341	1	1	10
23:28:14	44,0074	5,8194	-27,1	2	12,6	258	1	1	11
23:29:09	43,9827	5,7802	-16,4	2	16,3	251	1	1	5
23:29:10	43,9789	5,7571	-19,6	2	18,2	252	SAME	IDEM	7
23:29:24	44,2964	5,8509	-50,4	6	31,3	341	1	1	8
23:29:24	44,2828	5,8945	-17,3	1	28,9	347	SAME	IDEM	2
23:29:29	44,2201	5,9352	-12,1	1	21,4	351	1	1	3
23:29:56	43,9794	5,799	-42,8	3	15,1	248	1	1	11
23:30:08	44,2896	5,895	-65,6	4	29,6	347	1	1	13

23:30:11	43,9578	5,7736	-48,3	2	17,9	243	1	1	10
23:31:24	44,1173	5,8647	-19,2	1	13,1	318	1	1	2
23:31:49	43,9939	5,8032	-24,4	1	14,2	254	1	1	9
23:31:50	43,9658	5,7305	-15	1	20,7	250	1	1	3
23:32:19	44,286	5,8812	-37,1	2	29,5	345	1	1	11
23:32:21	44,0332	5,8127	-26,4	2	12,9	272	1	1	12
23:32:39	44,087	5,8701	-55,5	2	10,5	307	1	1	16
23:32:50	44,0397	5,9151	10,1	1	4,9	283	1	1	2
23:33:06							1	1	1
23:33:12	44,0605	5,8974	-17,1	9	7,1	299	1	1	5
23:33:20	44,3073	5,9042	-14,6	3	31,4	349	1	1	5
23:33:47	44,0896	5,8675	-51,8	4	10,9	308	1	1	14
23:33:49	44,0082	5,8251	-10,6	1	12,1	258	1	1	3
23:34:15	44,2536	6,01	-34,5	1	25,1	6	1	1	14
23:34:15	44,2549	6,0023	-24,6	3	25,2	5	SAME	IDEM	10
23:34:15	44,411	6,0764	-63,4	5	43,2	10	1	1	13
23:34:57	44,204	5,8695	-8,2	1	21,1	336	1	1	2
23:35:22	44,1452	5,9836	-9	1	12,9	3	1	1	2
23:35:43	44,2906	5,8985	-5,9	1	29,7	348	1	1	2
23:35:44	44,3272	5,878	-13,9	1	34	346	SAME	IDEM	3

Table 1 : Flashes observed and detected towards Ganagobie

Time	Latitude	Longitude	Current	Arcs	Distance	Azimuth	Mét. flashes	Obs. flashes	Sensors
23:36:36	44,022	5,7877	-10,8	1	14,9	267	1	1	2
23:36:37	44,1733	5,9419	-10	1	16,2	350	1	1	3
23:37:16	44,1388	5,949	-70,7	2	12,3	350	1	1	14
23:37:17	44,3076	5,9882	-67,3	4	31	2	1	1	18
23:37:25	44,1018	5,901	23,4	1	10	324	1	1	4
23:37:30							1	1	1
23:37:38	44,1146	5,9081	-52,7	2	10,9	330	1	1	19
23:37:41	44,0727	5,9084	-9,8	2	7,1	312	1	1	2
23:38:04							1	1	1
23:38:40	44,0222	5,8236	-99	1	12,1	266	1	1	7
23:38:43	44,1034	5,9204	-20,6	1	9,3	332	1	1	10
23:39:16			positive				1	1	1
23:39:18	44,1134	5,9255	-37,2	4	10,1	337	1	1	12
23:39:18	44,0752	5,8282	-11	1	12,7	293	1	1	4
23:39:19	44,0748	5,8313	-20,3	1	12,5	293	SAME	IDEM	6
23:39:37	44,115	5,9171	-58,8	8	10,6	334	1	1	19
23:40:07	44,1967	5,715	-25,5	1	27,8	312	1	1	3
23:40:11	44,3759	5,9919	-71,7	2	38,6	2	1	1	4
23:40:22	44,1352	5,9346	-105,5	2	12,2	344	1	1	15
23:40:38	44,1004	5,9699	-25,8	1	7,9	357	1	1	13
23:40:42	44,1509	6,0314	-13,1	3	14,3	18	1	2	3
23:41:02	44,1503	5,994	-30,8	3	13,6	6	1	1	11
23:41:06	44,1056	5,9684	-32,8	2	8,5	356	1	1	11
23:41:07	44,1054	5,9669	-48	2	8,5	356	SAME	IDEM	11
23:41:27	44,1549	5,9896	-66,2	13	14	5	1	3	10
23:41:28	44,1459	6,022	-12,9	1	13,5	16	1	2	3
23:41:43	44,1536	6,0339	-17,9	3	14,6	18	1	1	5
23:41:43	44,1556	6,0351	-10,4	2	14,9	19	SAME	IDEM	3
23:41:50	44,1752	5,9609	-12,9	3	16,3	356	1	2	2
23:41:55							1	1	1
23:42:03	44,1335	6,023	-18	2	12,2	18	1	1	7
23:42:04	44,0843	5,8743	17,5	1	10,1	307	1	1	2

23:42:16	44,1696	6,0039	-22,2	5	15,8	8	1	3	10
23:42:29	44,1806	6,0266	-32,9	13	17,3	13	1	1	3
23:42:33	44,139	6,0125	-9,2	3	12,6	14	1	3	3
23:42:40	44,2108	6,0891	-8,1	2	22,2	24	1	2	2
23:42:44	44,1853	6,0157	-15,4	1	17,7	10	1	1	2
23:42:46							1	1	1
23:42:48	44,1757	5,9654	-18,4	1	16,3	357	1	1	5
23:42:56	44,1526	6,036	-36,4	15	14,6	19	1	2	9
23:43:01	44,1598	6,0208	-20,6	4	15	14	1	1	4
23:43:09	44,2757	5,9726	-33,9	5	27,4	359	1	1	11
23:43:22	44,1423	5,9572	-18	4	12,6	353	1	3	4
23:43:26	43,7865	5,6192	-24,6	2	39,2	226	1	1	3
23:43:27	44,1993	6,0292	-22,7	2	19,4	13	1	1	5
23:43:31	44,175	6,0235	-28,8	6	16,7	13	1	1	6
23:43:32	44,1601	6,0214	-32,2	5	15	14	1	1	15
23:43:40	44,1566	6,0288	-13,8	6	14,8	17	1	3	2
23:43:49	44,1406	6,016	-16,8	6	12,8	15	1	3	5
23:43:57							1	1	1
23:43:59	44,1814	6,015	-35,6	2	17,2	10	1	3	10
23:44:00	44,1792	6,0092	-23,4	7	16,9	9	SAME	IDEM	9
23:44:05	44,112	5,9631	-15	2	9,2	354	1	1	3
23:44:14	44,1762	6,0374	-40,7	7	17,1	17	1	2	11
23:44:22	44,1592	5,9086	-18,3	2	15,4	340	1	1	6
23:44:30	44,187	6,0579	-33,5	7	18,8	20	1	3	9
23:44:41			negative				1	1	1
23:44:52	44,4239	6,0386	-60,4	1	44,2	6	1	1	4
23:44:55	44,1585	6,036	-26,2	4	15,2	18	1	1	7
23:44:58	44,1914	6,0432	-23,7	6	18,8	16	1	3	5
23:45:04	44,2073	6,0771	20	1	21,4	22	1	1	3
23:45:10	44,1497	6,0521	-15,1	1	14,8	24	1	1	6
23:45:10	44,1447	6,0349	-26,8	3	13,7	20	SAME	IDEM	13
23:45:24	44,1928	6,015	-23,1	13	18,5	10	1	2	10
23:45:25							SAME	IDEM	
23:45:34	44,1641	6,0198	-16	2	15,4	13	1	2	6
23:45:53	44,1801	5,9921	-8,2	6	16,8	4	1	1	2
23:45:58	44,2081	6,0427	-9,7	5	20,6	15	1	3	2
23:46:15	44,1767	6,0329	-15,4	2	17	15	1	2	2
23:46:17	44,2379	5,941	-18,9	3	23,3	353	1	1	5
23:46:17	44,191	6,0614	-16,4	2	19,3	21	1	1	6
23:46:18	44,2573	6,0206	-25,2	3	25,6	8	1	1	10
23:46:36	44,0927	5,8349	-16,9	3	13,2	302	1	1	5
23:46:36	44,0689	5,7864	-19,2	2	15,6	286	1	1	2
23:46:43	44,174	6,0427	-9,3	2	17	18	1	2	2
23:46:47	44,153	6,0141	-20,7	2	14,1	12	1	1	10
23:46:48	44,1479	6,0048	-14,5	1	13,4	10	SAME	IDEM	4
23:46:52	44,2123	6,0286	-18,1	6	20,8	12	1	3	4
23:47:08	44,1775	5,9306	-15,4	2	16,8	348	1	1	2
23:47:14							1	1	1
23:47:28	44,1949	6,0554	-16,4	7	19,5	19	1	2	3
23:47:33	44,3743	6,0298	-12,2	1	38,6	6	1	1	2
23:47:33	44,3888	5,9919	-19,8	1	40	2	SAME	IDEM	5
23:47:37	44,1266	5,9926	-17,3	5	10,9	7	1	1	5
23:47:43	44,183	5,9905	-17,2	4	17,1	4	1	1	5
23:47:44	44,1856	5,9793	-9,9	2	17,4	1	SAME	IDEM	2
23:47:45	44,1896	5,9718	8,7	1	17,8	359	1	1	2
23:47:51	44,2327	6,0611	-18,2	4	23,7	16	1	2	3
23:47:52	44,2325	6,0592	-15,2	2	23,6	16	SAME	IDEM	4
23:48:04	44,1876	6,0584	-18,6	11	18,8	20	1	1	6
23:48:06	44,1827	6,0213	-10	1	17,5	12	SAME	IDEM	2
23:48:16	44,1908	6,0094	-13,9	5	18,2	8	1	1	2
23:48:27	44,2342	6,0843	-19	6	24,4	21	1	3	4

23:48:33							1	1	1
23:48:43	44,3711	5,9866	-8,3	3	38	1	1	1	3
23:48:46	44,2105	6,0431	-21,7	5	20,9	15	1	2	5
23:48:56	44,2064	6,0859	8,3	1	21,6	24	1	1	2
23:48:57	44,2196	6,0635	-15,6	4	22,3	18	1	3	5
23:49:04	44,1965	5,9945	-11,6	1	18,7	4	1	1	2
23:49:15	44,219	6,0328	-10,9	1	21,6	12	1	1	3
23:49:16	44,1862	6,055	-9	2	18,6	20	1	1	3
23:49:28	44,1989	5,9631	-9,8	2	18,9	357	1	1	2
23:49:29	44,1948	5,9631	-19,3	2	18,4	357	SAME	IDEM	4
23:49:32	44,2231	6,0398	-26	2	22,2	13	1	1	7
23:49:52	44,2192	6,0287	-14,4	6	21,6	11	1	2	4
23:49:53	44,1747	6,0498	-25,1	3	17,3	20	1	1	12
23:50:12	44,1646	5,9895	-13,2	3	15,1	4	1	1	5
23:50:13	44,2111	6,0246	-20,3	2	20,6	11	1	1	10
23:50:25	44,2556	6,089	-19,3	2	26,8	19	1	2	6
23:50:29	44,3944	5,9973	-13,7	1	40,6	2	1	1	4
23:50:46	44,2017	6,0114	-54,4	4	19,4	8	1	1	14
23:50:51	44,2225	6,0459	-7,8	1	22,2	14	1	1	2
23:51:00	44,1783	6,0478	-12,6	6	17,6	19	1	2	3
23:51:02	44,1573	5,9109	-11,4	1	15,1	340	1	1	2
23:51:11				3			1	1	1
23:51:17	44,1972	6,0317	-6,5	9	19,2	13	1	1	2
23:51:30	44,3051	6,0319	-48,5	1	31	8	1	1	13
23:51:30	44,3249	6,0133	-19	1	33	5	SAME	IDEM	7
23:51:31	44,3003	6,0184	-36,1	1	30,3	6	SAME	IDEM	8
23:51:35	44,407	6,0593	-20,3	1	42,5	9	1	1	7
23:51:44	44,2384	5,9639	9,1	5	23,3	357	1	1	2
23:51:48	44,3847	6,0164	-18,5	2	39,6	4	1	1	3
23:51:48	44,422	6,0045	-14	2	43,7	3	SAME	IDEM	5
23:51:54	44,2481	6,0675	-13,2	4	25,4	16	1	1	4
23:52:05	44,1967	5,8849	15,2	3	19,9	339	1	1	2
23:52:17	44,2062	6,0714	-18,6	5	21,1	21	1	1	3
23:52:19	44,2155	6,0617	-5,7	1	21,8	18	1	1	2
23:52:26	44,2581	6,1068	-19,6	4	27,5	22	1	1	4

Table 2 : Flashes observed and detected towards Les Mées village

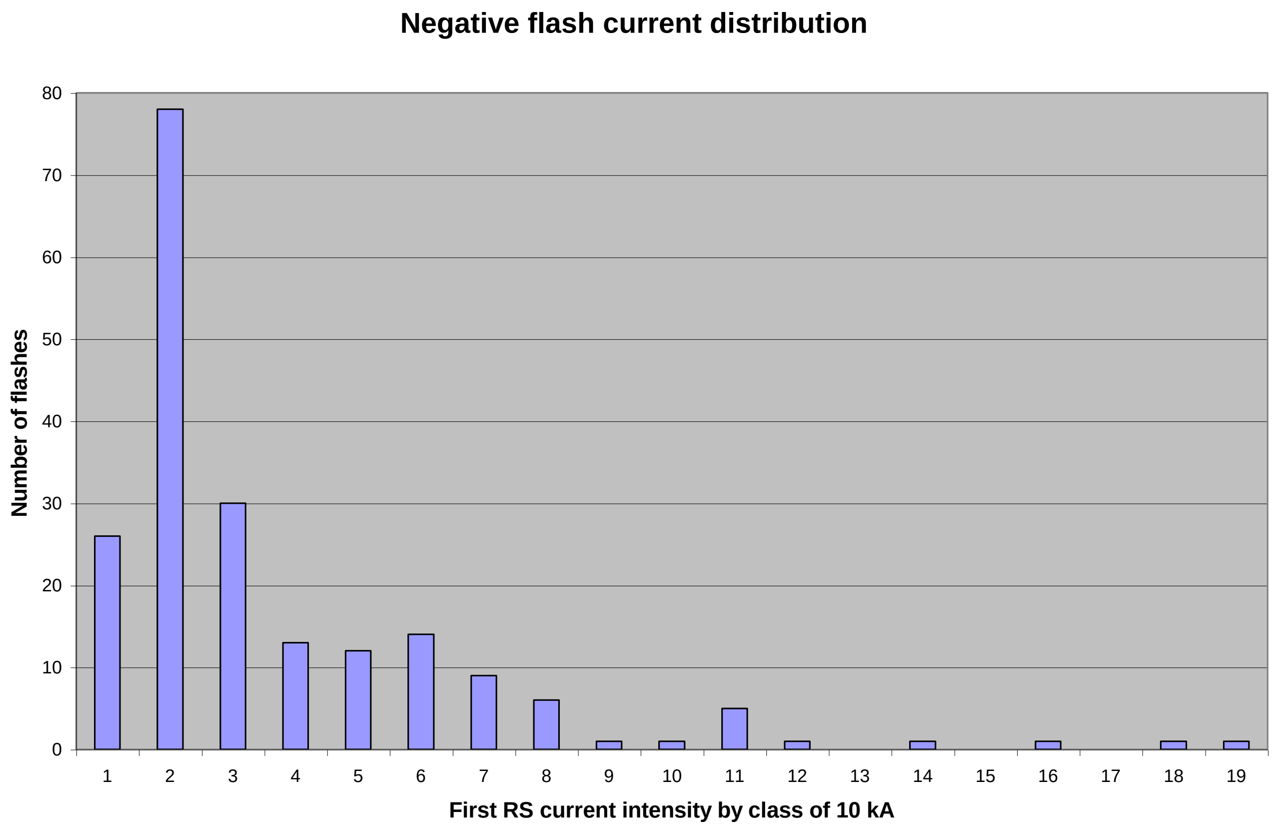
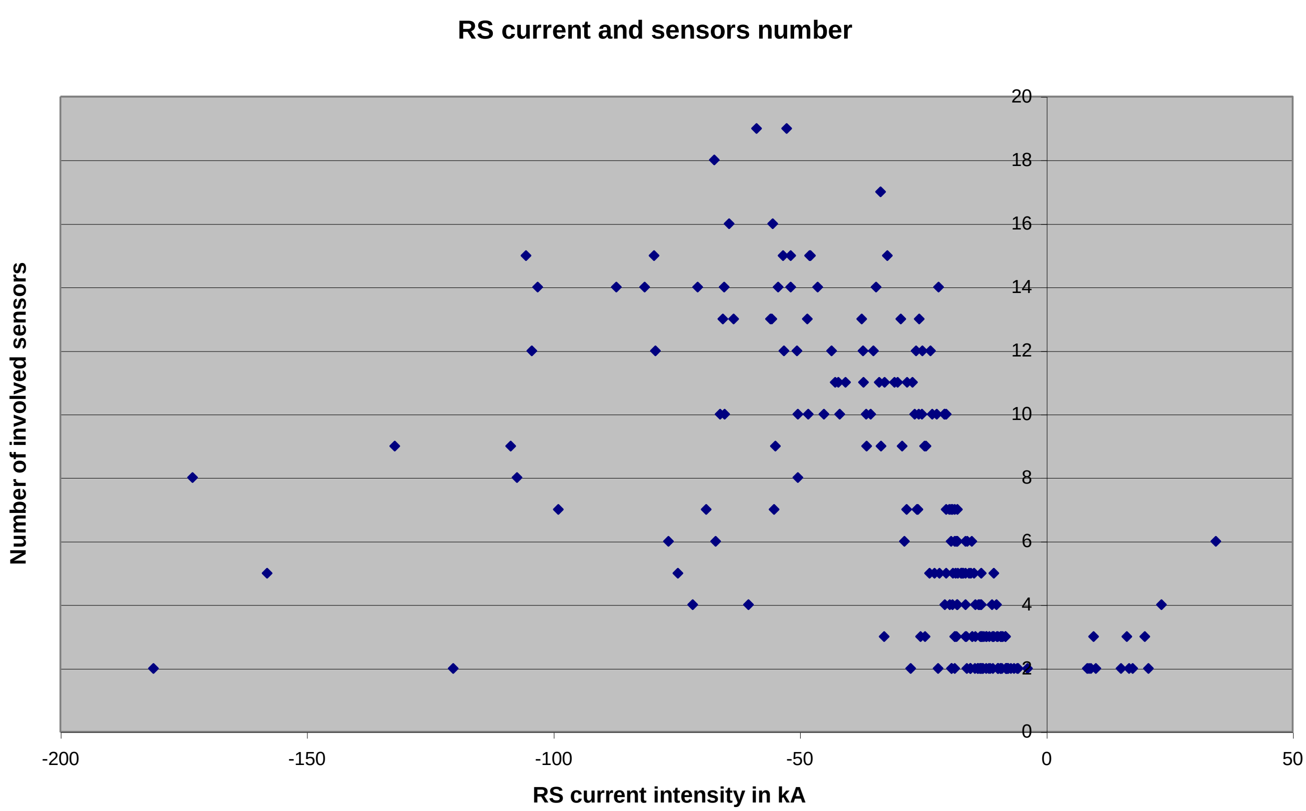


Figure 5 : Negative First RS current distribution

Figure 6 : Correlation between RS current and number of sensors involved in location



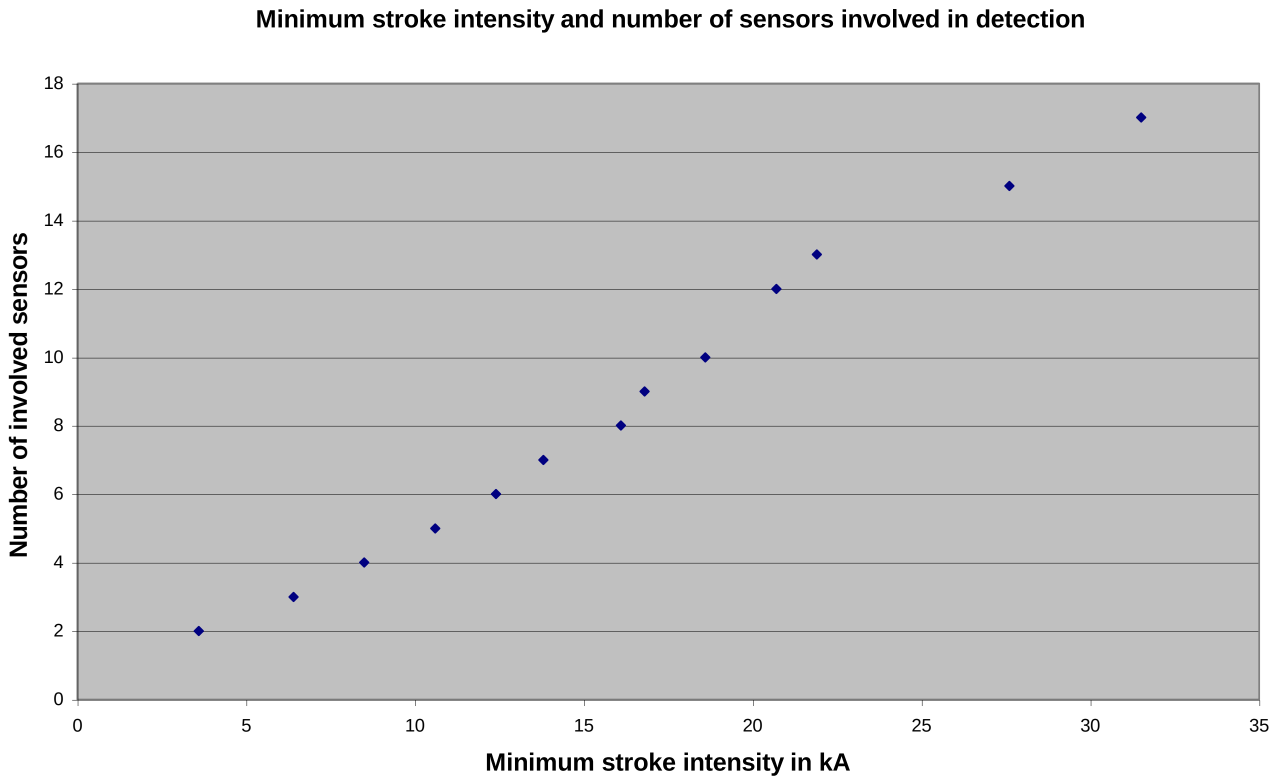


Figure 7 : Minimum stroke intensity and number of sensors involved in detection

Figure 7 shows that a minimum stroke intensity is linked to the detection by a given number of sensors. For instance, a 10 kA stroke cannot be detected and located by more than 4 sensors. Of course, no stroke can be located by only one sensor.

Discussion on multiple channel flashes

A very detailed study of multiple channel flashes may be found in [**2002,Valine and Krider**], [**2000, Hermant**], [**1996, Berger**], [**1984, Thomson**]. After studying 10511 flashes, we found that 67% of flashes exhibit a single channel. 23.5% have two separate channels, 7% three, 2% four, 0.4% five, 0.1% six. One exceptional flash has shown seven channels. Generally, they have a common root at high altitude, not visible when cloud bottoms are at low altitude.
According to us, this may explain why it is so difficult, even for the Observer, to account for the real number of flashes, so, it is necessary to deal only with strokes data and not with flashes data.

Conclusions : Where to improve Lightning Detection Networks ?

Let us remind that the purpose of our studies is not only to assess the detection efficiency of a given national network, but also to use available data to understand why some of the flashes are fully detected and why some others are not seen by the network.

First, we have to estimate some problems inherent to the testing procedure. For comparison purpose, the studied thunderstorm has to be as simple as possible. That is to say the studied thunderstorm preferably must contain few flashes, well separated in space and time. The distance from the observer has to be large enough to cover most of the flashes, but not too large to ascertain their visibility. For distances less than 10 miles, thunder time-of-arrival should be useful to help lightning location. The discrimination between long duration luminosity (either CG flashes or IC flashes) and real CG flash is difficult when cloud bottoms are low, especially under raining conditions. The use of two cameras aiming directions at right angle would be helpful, but not realistic because of the orography (difficulties of access) and the random trajectory of the cloud cells. A prospective improvement would be to use electric field recording, which would make easier to discriminate between CG and IC flashes, and take into account some weakly luminous flashes not easily detectable by the Observer, especially when raining.

A more important issue is to know what is the meaning of the locations computed by the network. For example, it is quite obvious that a network does not deliver the location of a real impact but an optimal location, compromise between two or more directions from where an impact occurred, though the use of time-of-arrival data is very helpful. If the flash is oblique (not vertical), what is the meaning of the impact location (only an average position of the flash channel)?. When there are several restrikes with different impacts, it is impossible to determine if we have to manage with one flash or several. A same uncertainty occurs when during a multiple flash, an IC episode happens between restrikes of various channels. At last, we wonder how is it possible not to detect a flash among others correctly detected (amplitude, tortuosity, timing, …). These questions infer that a better knowledge about the detection principles has to be acquired. This is the goal of our further investigations.

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