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Comparison between high-speed video recordings of lightning and the detections of the Catalan Lightning Location Network (XDDE)

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Abstract

Lightning detections of the Catalan Lightning Location Network (XDDE) are compared with high speed video recordings carried out in Spain during summer 2009. At that time the XDDE was composed by four sensors: two SAFIR 3000 type and two LS8000 type. The comparison showed good agreement in the observations at the center and at the south of the network. However, the observations recorded at the north of the network showed a poorer detection efficiency and location accuracy. On the other hand, the fine comparison between frame by frame of video recordings and network detections reveals that the network often detects mostly intra-cloud (IC) sources which probably belong to the preliminary breakdown in downward cloud-to-ground flashes. In some cases few sources are detected during steeped leaders toward to the ground. In the case of our observed IC flashes, the detected sources never corresponded to observations of propagation leaders, if not, small burst of detections were linked to permanent illuminated channels or permanent visible luminosity from the cloud.

1. Introduction

Recently, digital high speed videos of natural lightning at several thousands of frames per second have provided useful information about lightning processes (e.g. Saba et al. 2006, 2008, 2009). On the other hand, video records of lightning are a common information used for the evaluation of lightning location networks (e.g Kehoe and Krider 2004 or Montanyà et al. 2006). Taking the advantage of the preliminary experimental campaigns related to the future ASIM (Atmosphere-Space Interaction Monitor) mission of the ESA, during summer 2009 video recordings of lightning at 10000 fps were carried out over the northeastern region of Spain. Additionally, close electric fields and x/gamma rays detections where simultaneous recorded (figure 1). All records where time stamped within 1 µs with the GPS time. The region of observation is well covered by the Catalan Lightning Location Network (XDDE) (Montanyà et al. 2006). At that time the XDDE was composed by four interferometers where two of them were SAFIR 3000 type and the other two were LS 8000 type (figure 2).

We have recorded lightning in 13 thunderstorm episodes located in 4 different sites corresponding to the north, center and south of Catalonia. More than 60 videos were obtained but only 41 were suitable for comparison with the XDDE due to time synchronicity problems.

a) b)

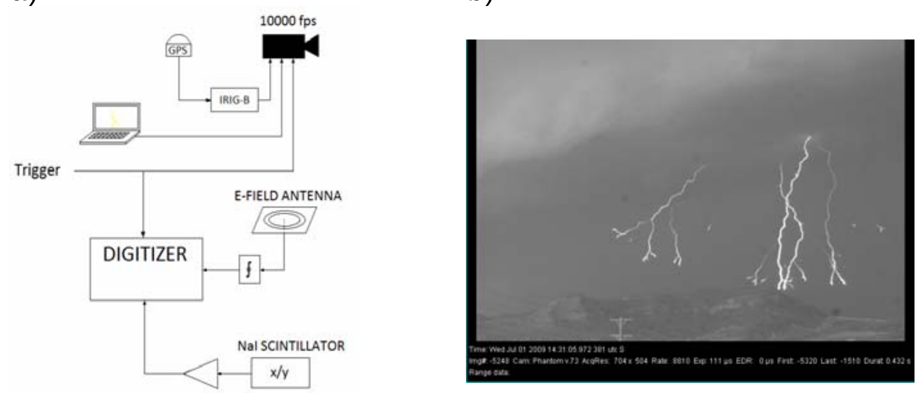


Figure 1. a) Scheme of the instrument; and b) frame of several downward leaders to ground of the same flash.

First the paper presents the general results of the comparison between lightning video observations and network detections. Then, the paper includes two examples of the analysis of frame by frame video with the detections of the XDDE network.

2. General network performance

The locations of the SAFIR and LS8000 sensors in the XDDE network (blue circles) are displayed in figure 2. The observations of lightning were carried out in four areas of the Catalan region (grey circles with numbers) ranging the north, center and the south of the region. In the observations at the north (circles marked with 7 and 17), the network missed some of the observed CG and IC flashes. Also in these areas the network detected correctly in time several observed CG flashes but with wrong locations rotated 90º to the left of the field of view. On the contrary, the observations at the south (circle marked with 25) presented a very good agreement. Also observations in the center (circle marked with 75) showed good detection agreement but in very few cases wrong locations occurred.

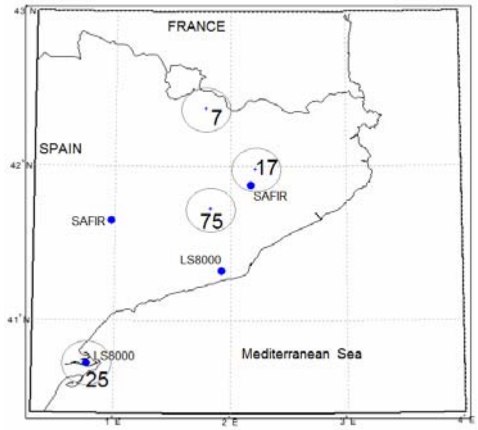


Figure 2. Locations of the SAFIR and LS8000 sensors (blue filled circles) and the observation sites (grey circles with numbers). The numbers in the circles indicates the number of VHF soureces per flash observed in the region.

Figure 3 resumes the general agreement between the video observations and the network detections. A 39 % where flashes correctly detected (*Ok* in figure 3) while 29 % where detected but located in a wrong direction (*Ok but wrong location* in figure 3). Then, 32 % of the recorded flashes where not detected (*Not ok* in figure 3). Among the correct detected flashes practically one half were CG flashes while the other half were IC flashes.

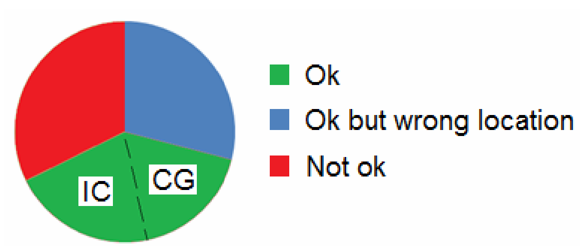


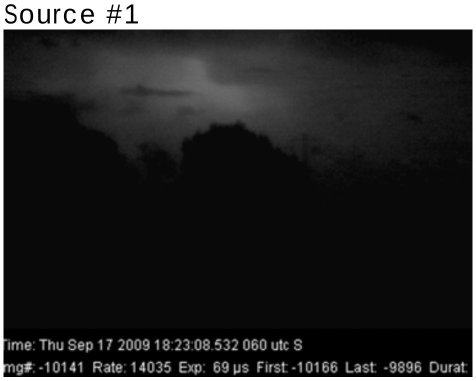
Figure 3. General results of the comparison between video observations and the detections by the XDDE. 39 % corresponded to correctly detected and located flashes (Ok type); 29 % corresponded to detected flashes but not correctly located (Ok but wrong location type) and; 32 % of the observed flashes were not detected.

The low detections present in the northern videos may be due to the mixture of the sensor type during that time. Specially, the miss detections of CG flashes can be due to the different method that each sensor type employs. A similar performance is obtained analyzing the number of VHF detections per flash in the four observing areas. The numbers in figure 2 indicate the average number of VHF sources per flash. The obtained numbers also presents more detections per flash at the center and at the south while the number strongly decrease for the flashes occurred at the north.

3. Frame by frame analysis of two flashes

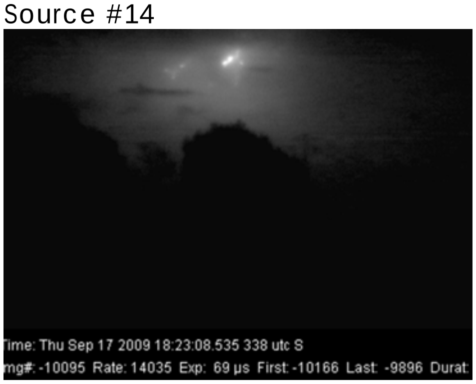
Thanks to the high accuracy of the video frame time stamping we can show what we watch at the video for each individual VHF detection. The first flash presented corresponds to a negative CG flash on 20090817 at 18:23:08. In that flash 18 VHF sources where located forming a path of 6 km long. Figure 4 displays six frames of the event. From the frame corresponded to the detection #1 to the #15 the network detected a source every 100 µs. In the frames corresponding to the first thirteen sources practically constant light at the cloud base were observed without any channel or leader visible. The frames of sources #14 and #15 occurred at the initial part of the downward visible leader and when the leader touched ground. At the time of the return stroke the source #16 was detected. A couple of more sources were detected just after the return stroke.

Source #1

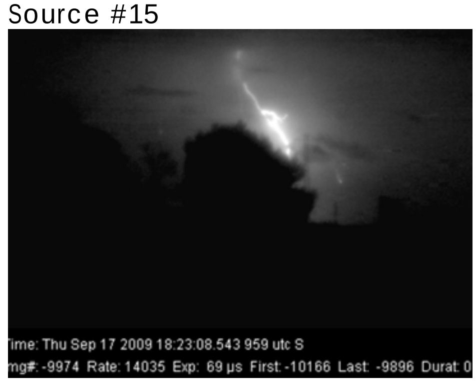


Source #13

Source #14



Source #15



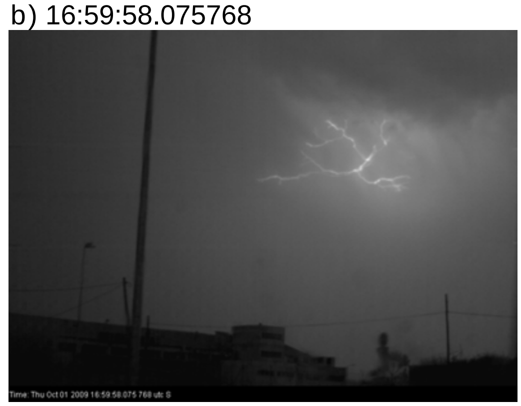
Source #16

Figure 4. Frames of the negative CG flash on the 20090917 at 18:23:08. On top of each image the detected VHF source number is indicated.

The next flash presented corresponds to the 20091001 flash at 16:59:58. In this case the flash was IC. In the figure 5 only four frames are included. At 16:59:58.073 (figure 4a) a very bright light saturated the camera. Just after, at 16:59:58.075 (figure 4b), several leaders where observed propagating in all directions at the cloud base. At that moment, there was not any detection. The leaders propagated until 16:59:58.256. At 16:59:58.256 (figure 4c) a brighter light than the first saturated again the camera. At that moment the XDDE started to detect sources until 16:59.58.2615 (figure 4d). A total of 15 sources were detected, and during this period the channel was continuously illuminated.

a)16:59:58.073657

b) 16:59:58.075768



c)16:59:58.256342 Source #1

d)16:59.58.261573 Source #15

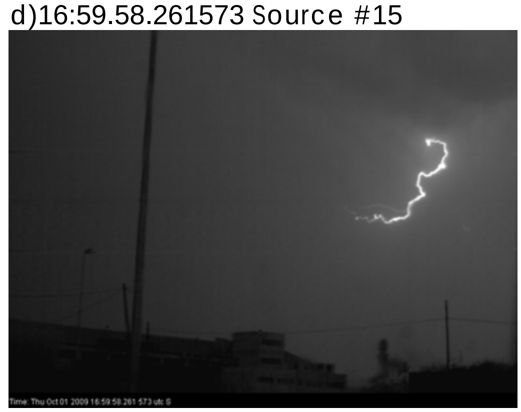


Figure 4. Four frames of an intra-cloud lightning occurred on 20090110 at 16:59:58. The time of this frame is indicated as well the corresponding VHF source number.

4. Discussion and conclusions

The analyzed high speed videos of CG flashes have revealed that the network often detects mostly intra-cloud (IC) sources which probably belong to the preliminary breakdown in downward cloud-to-ground flashes. In some cases few sources are detected during steeped leaders to the ground. However, since the number of sources changes among different regions within the network the results can be affected. In the case of IC flashes, the detected sources no corresponded to observations of propagation leaders if not, small number of detections which were linked to permanent illuminated channels or permanent luminosity from the cloud.

The XDDE is limited to a time resolution of 100 µs. With such limitation it is difficult to compare the type of detections with the measured by Richard et al. 1986. In that work, two types of emissions where observed: low-rate pulsed emissions and burst of pulses. The first type corresponded to rates below 20 pulses/ms while the burst lasted from several hundred microseconds to a few milliseconds. The low-rate type were associated with important IC charge transfers while the burst were associated with highly organized propagation of sources in the 10^7 m s^{-1}. We cannot precisely classify our observations, but from the changes measured by means of the electric field antenna, the low-rate type seems to be the phenomenon associated with IC detections.

The paper presented the comparison between the video observations and the XDDE detections. At the time of the observations the network was composed by two SAFIR 3000 sensors plus two LS8000 but after October 2009 the network was finally full upgraded to LS8000. Since the capabilities of the LS8000 substantially improved the old SAFIR sensors we plan to conduct a similar campaign during 2010.

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