2010 21st International Lightning Detection Conference
19 - 20 April • Orlando, Florida, USA
3rd International Lightning Meteorology Conference
21 - 22 April • Orlando, Florida, USA

ANALYSIS OF THE GEOGRAPHICAL CONFIGURATION OF A LIGHTNING DETECTION NETWORK AND ITS INFLUENCE IN THE ACCURACY OF LIGHTNING LOCATION

J. López[1,2], M. Murphy[3], J.A. Aranda[4], S. Gaztelumendi[1,2], M. Maruri[1,2], D. de la Vega[5]

[1]Basque Meteorology Agency (EUSKALMET), Miñano (Álava), Spain
[2]European Virtual Engineering Technological Centre, Meteorology Division, Vitoria-Gasteiz (Álava), Spain
[3]VAISALA, Tucson (Arizona), US
[4]Meteorology and Climatology Directorate, Basque Government. Vitoria-Gasteiz (Álava), Spain
[5]University of the Basque Country, Bilbao (Vizcaya), Spain

1. Introduction

The geographical configuration of the sensors in a lightning detection network (LDN) is a prime factor that must be considered in the data quality. In this paper, a study of the influence of the location of sensor sites for lightning data quality detected by the Basque Country Lightning Detection Network will be presented.

The number of sensors making up the regional LDN depends on the desired redundancy in the system, and the total pricing of the final system. For some applications, the ability of the LDN to detect lightning outside the territory is also important. For areas outside the territory, the accuracy of lightning localization is determined by the relative location of the sensors.

The purpose of this study is to figure out how the geographical distribution of the sensors in a regional network affects the accuracy of the lightning detections.

The paper is structured as follows. Section 2 presents the configuration of the Basque Country Lightning Detection Network. Section 3 provides overall statistics of the whole period and the area over which the network operates. In Section 4 the confidence areas for certain regions is analyzed, determining the accuracy for different regions within the service area. The conclusions and the further work are covered in Section 5.

2. Configuration of the BCLDN

The regional lightning detection network in the Basque Country has been fully operative since November 2008 (Gaztelumendi et al, 2009). It is composed of four LS8000 sensors, performing total lightning detection of both intra-cloud (IC) and cloud-to-ground (CG) events. During the site selection process, the range of detection for the service area in the Basque Country was ensured, taking into consideration the geographical and administrative restrictions for selecting the most appropriate sites. Figure 1 depicts the locations selected for the sensors, and Figure 2 shows the expected accuracy for the actual configuration of the network.

Fig. 1. Current disposition of the four sensors of the BCLDN

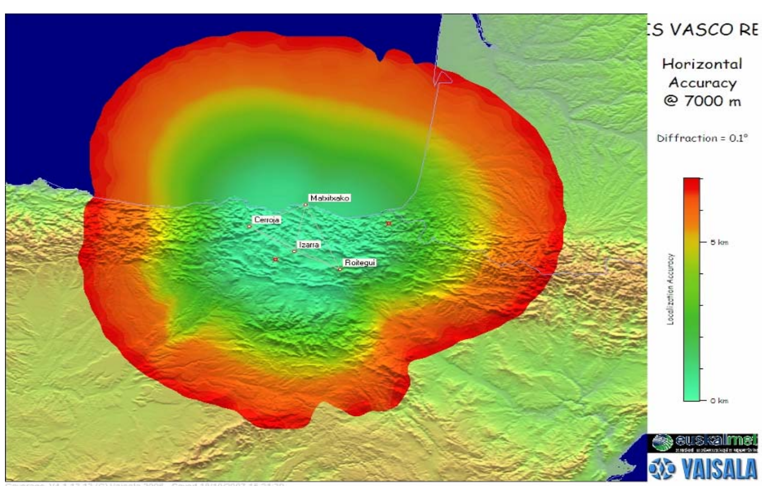

Fig. 2. Expected accuracy of the network with the current site configuration

During the summer and the first months in the autumn of 2008 weekly data was provided to Vaisala for performing the calibration process. The network became operative in November 2008. The data quality acquired by the network is accurate with the current disposition of the sensors, and lightning events are precisely located within the territory. However, the current disposition of three of the sensors (Cerroja, Beluntza and Roitegi) leads to less accuracy in the SE and a semi-blind region near the line formed by the three sensors (as long as Matxitxako participates, good solutions may still be observed in areas close to the line).

3. Network statistics in whole network area

For the analysis that must be performed, data from the lightning impacts detected over the first year of operation of the network (Nov'08 – Nov'09) have been gathered (Gaztelumendi, 2009).

The analysis of the data includes the calculation of a full set of statistics, taking into account certain parameters retrieved by the network and regarding the accuracy of the events detected. The accuracy is determined by a confidence ellipse for each stroke detected. These confidence ellipses represent the area where the impact has a particular probability of occurrence (being the central point the most probable one), and they are defined by the network by the lengths of their semi-major and semi-minor axes (Vaisala, 2004). The overall set of statistics for the network includes the mean and the median values of the semi-major axis of the confidence ellipses, peak current values and geographical distribution of the accuracy and positive CG strokes. Special emphasis will be done with respect to the accuracy values, as they will show how the network performs.

First, the detections in the entire period will be analyzed for a 90 km circle centered in the Basque Country. This circle includes the whole territory of the Basque Country and surrounding regions, such as the seaside and the mountainous regions in the East. This area has been selected in order to cover the entire territory and some surrounding interest areas.

3.1. CG stroke detection in the entire period

The strokes detected depending on the number of sensors contributing to the final solutions have been analyzed and a calculation of the median value of the semi-major axis of the confidence ellipses is shown in Fig. 3. The number of sensors directly affects the final accuracy of the calculated solutions (Fig. 4.), therefore this analysis provides useful information about the accuracy as a function of the number of sensors contributing to the solution.

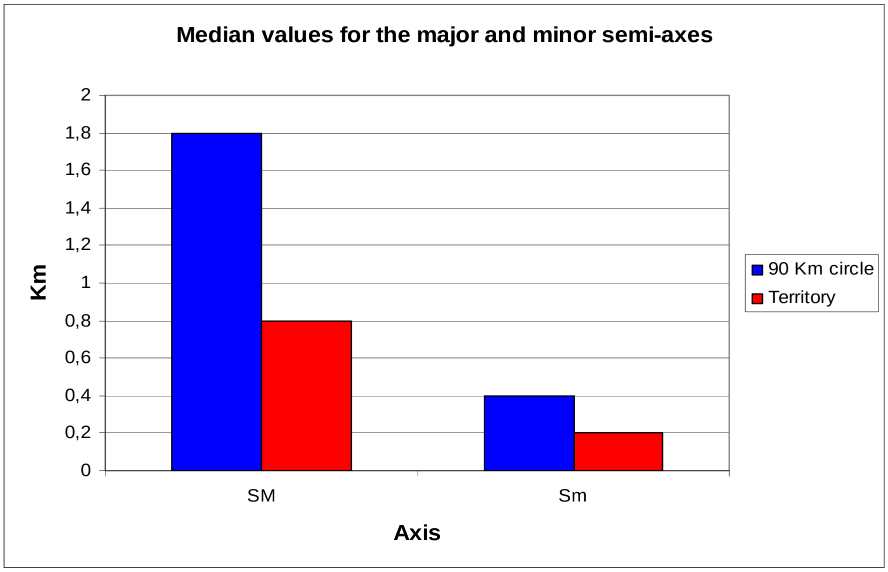

Fig. 3. Median values for the semi-major and semi-minor axes of the CG strokes

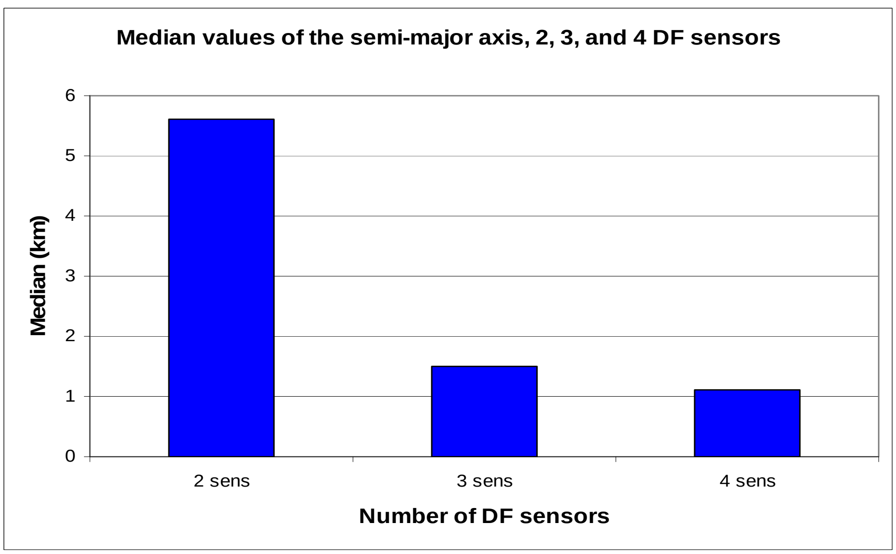

Fig. 4. Median values of the semi-major axes of the confidence ellipses for strokes detected with 2, 3 or 4 sensors

The geographical distribution of the sensors affect mainly the region to the SE outside the borders of the network, and it also affects to a lesser degree areas in the network interior that lie close to the line formed by three of the sensors. Figure 5 clearly shows how the location data in the area of the Basque Country is accurate. As illustrated in the figure, the errors are higher as the distance from the center becomes bigger. This fits the expected accuracy of the network, presented in Fig. 2.

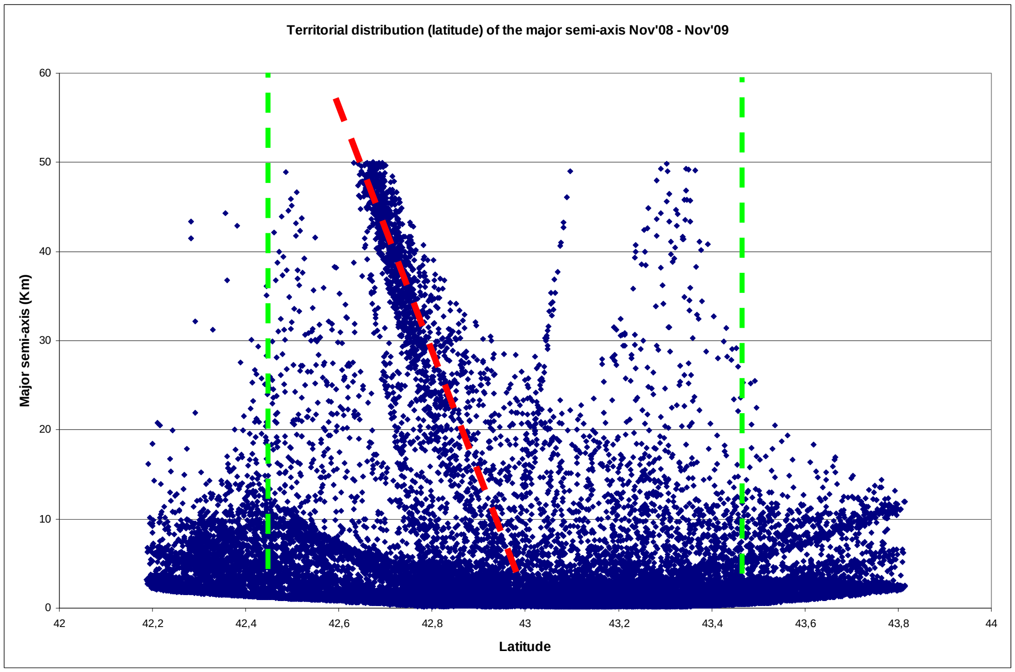

Fig. 5. Territorial distribution of CG detections (lat)

The picture shows the distribution of the CG detections in latitude. Taking into account that the maximum and minimum latitude values for the territory of the Basque Country are 43.45º, 42.45º (represented as green dashed lines), it is easy to determine in which regions the bigger confidence areas are obtained. The geographical disposition of the sensors directly affect the size of the confidence areas for the detected strokes and, therefore, the probability of low-quality locations for the strokes within these areas is higher (red line).

4. Network statistics of independent areas

Six different areas defined as 10 km circles have been defined in the Basque Country for determining those regions where detection with greater or lesser accuracy is attained due to the geographical configuration of the network.

These six areas have been selected in order to match three principal types of regions: coastal areas, interior areas and eastern areas. As the geographical disposition of the lightning detection sensors directly affects the location accuracy of the detections in the eastern border of the territory, a special interest must be driven into this region.

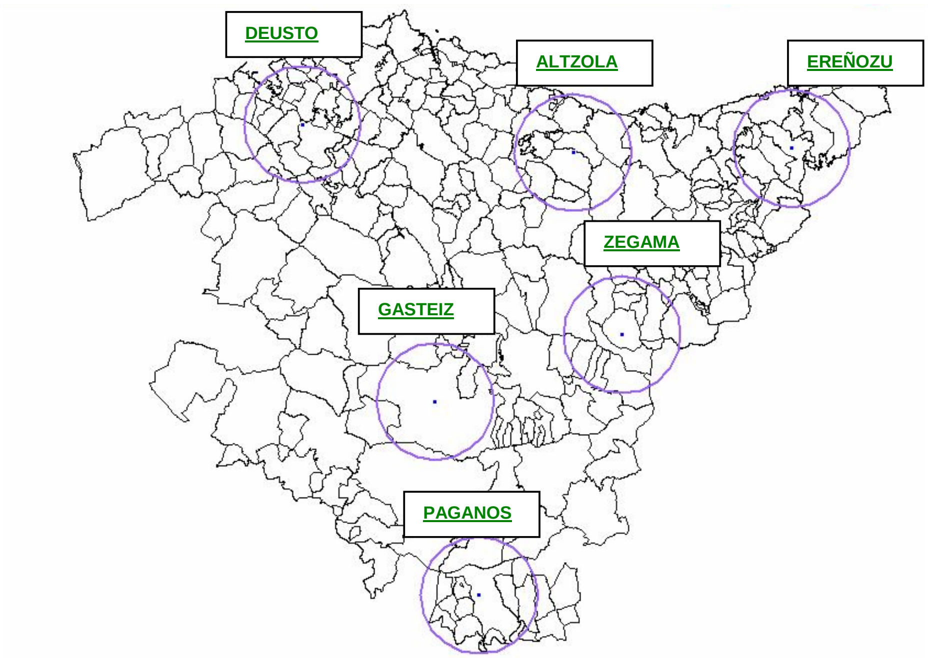

Fig. 6. Distribution of the six selected areas over the Basque Country

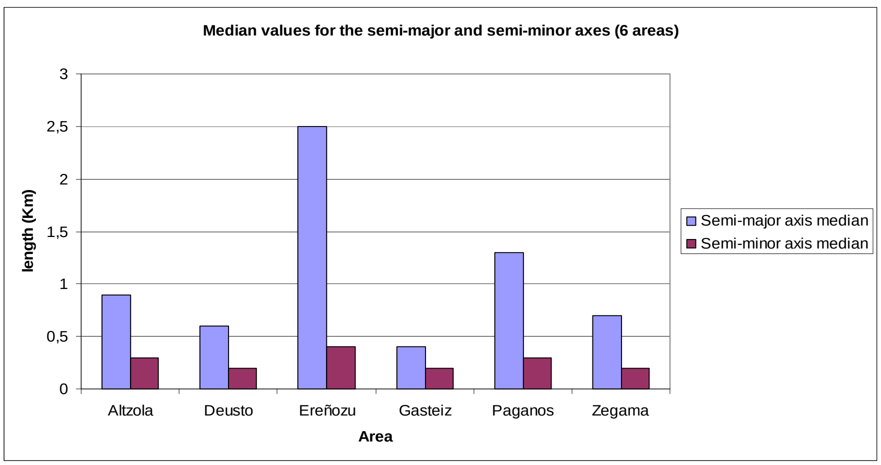

Fig. 7. Accuracy in the six analysis areas

Figure 7 represents the median values of the semi-major axis for the lightning strokes detected in the six areas under study. The length of the semi-major axes is the most useful value, showing higher uncertainties in those regions located close to the eastern border: Ereñozu, and Paganos. The most accurate detections were performed in the interior (Gasteiz) and in one of the coastal areas.

This is clearly dependent on the disposition of the sensors in the network. Combinations of triangulation and time-based localizations are better performed in the inner part of the territory. Figure 8 shows the number of sensors participating in the detections in the different areas. Once again, Ereñozu and Paganos have a greater number of detections with only 2 sensors participating, leading to poorer accuracy. Gasteiz and Deusto, which are the best regions among the selected, together in this case with the other two, have the most of their detections with 4 or 3 sensors participating.

Depending on the number of sensors that contribute the final solution, the accuracy of the detection may vary. In Fig. 8. the distribution of the percent over the total number of detections in each area depending on the number of sensors contributing to the solution is presented. The accuracy is represented in the size confidence ellipses, as it can be seen in Figures 9, 10 and 11. These figures clearly show those areas that are being more affected by the geographical distribution of the sensors.

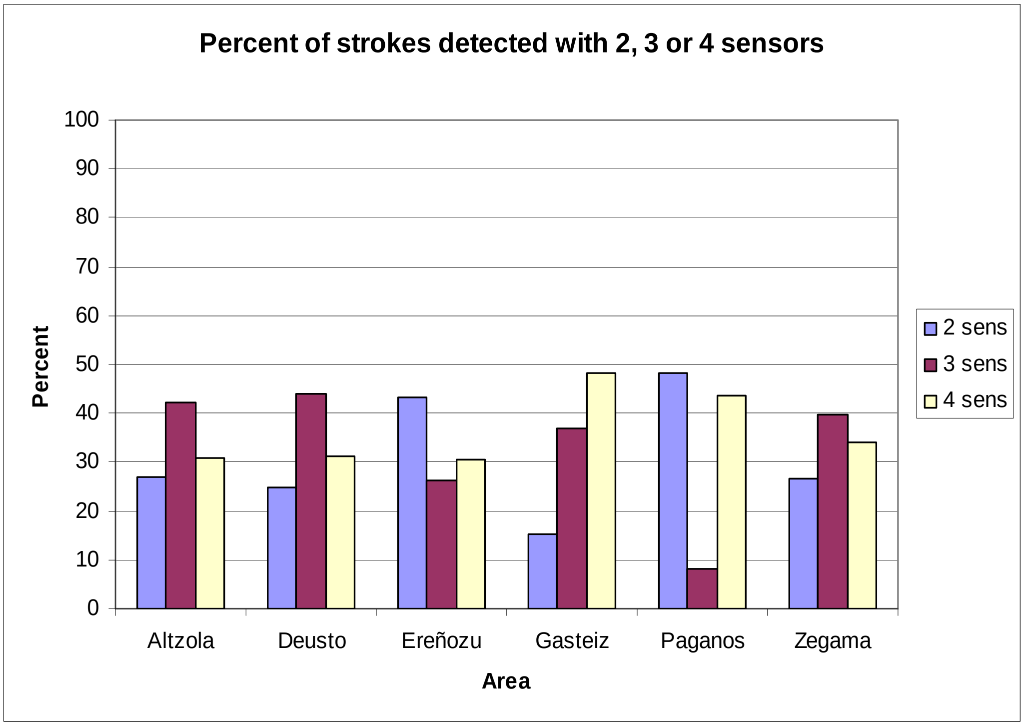

Fig. 8. Percent of strokes and sensors participating in the different regions

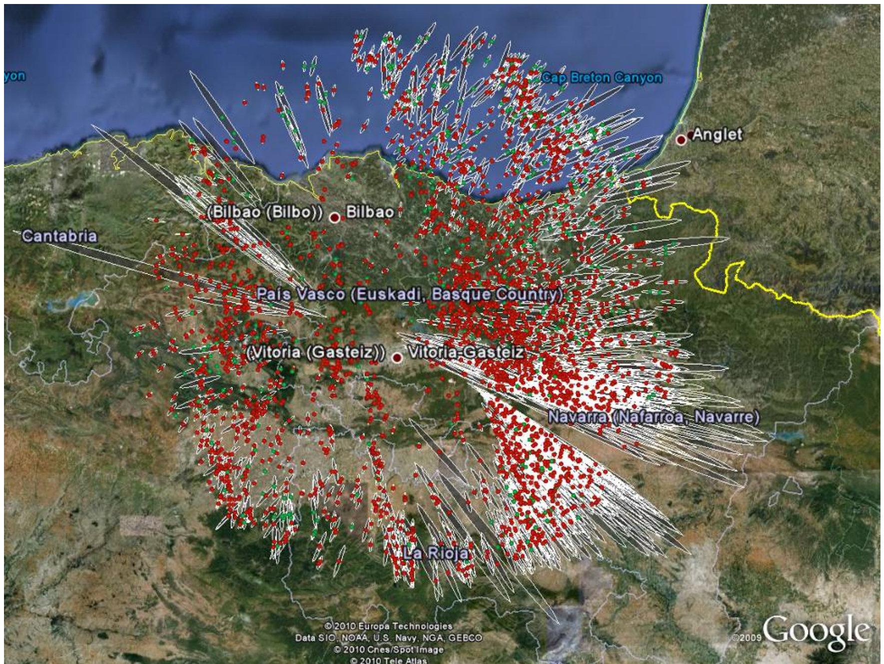

Fig. 9. Detections on May 24th, 2009

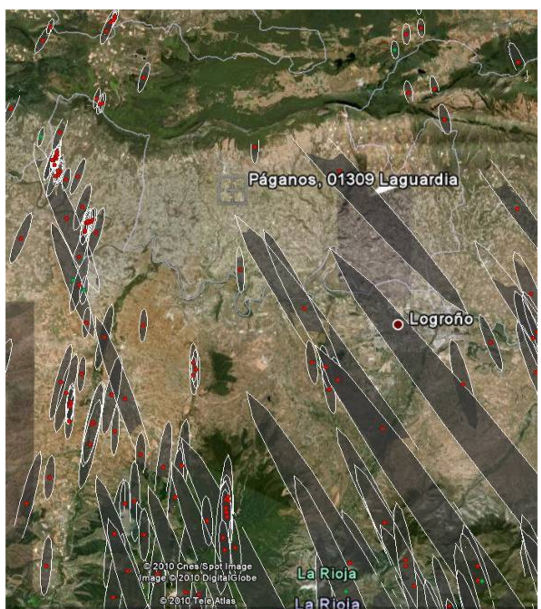

Fig. 10. Detections on May 24th, 2009, in the area of Paganos

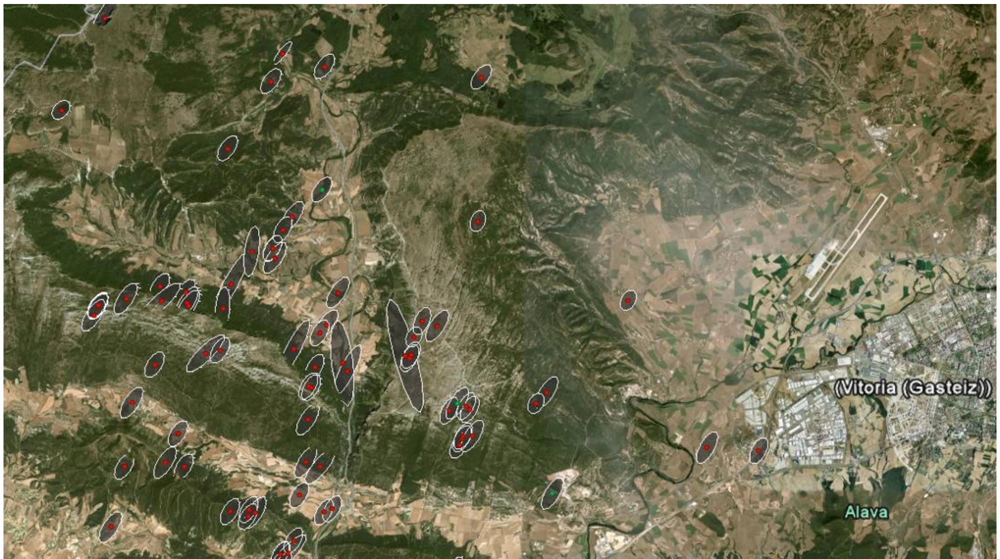

Fig. 11. Detections on May 24th, 2009, in the area of Gasteiz

5. Conclusions and further work

The study of the network performance is absolutely necessary when a long period of data is available (Orville, 2002). This must be carried out in order to identify the possible improvements needed for a better performance of the network. The research that is being performed in the Basque Country has allowed the identification of the main drawback of the network, and it has been proven how the geographical distribution of the sensors affects the performance of regional and local LDNs.

In this paper an exhaustive analysis of how the geographical disposition of the sensors affects the performance of a lightning detection network has been presented. In some cases, the geographical and administrative constraints limit the possibilities during the site selection process, and small networks may have limited location accuracy in some specific areas, as redundancy is not available. This drawback may not be significant in networks composed of a high number of sensors, relying on a higher redundancy level, but it has been proved that this is a critical situation for regional and local lightning detection networks.

The geographical distribution of the sensors in a network without redundancy directly affects the accuracy of the detections. The inaccuracies may be reduced in larger networks where redundancy is ensured.

The work in the future must be focused on the installation of a fifth sensor, located in the NE of the coverage area, that improves the location accuracy in this area, as it has been identified as one of the most sensitive areas for data quality.

References

Gaztelumendi, S. , López, J. , Egaña, J. , Maruri, M. M. and Aranda, J. A. , 2009: The Basque Country Lightning Detection Network, European Lightning Detection Workshop, Pau (France)

Gaztelumendi, S. , López, J. , Egaña, J. and Aranda, J. A. , 2009: Preliminary Results from Lightning Detection in the Basque Country, 5th European Conference on Severe Storms, Landhust (Germany)

Vaisala, 2004: Technical Note. Introduction to Lightning Detection

Orville, R. E. , Huffines, G. R. , Burrows, W. R. , Holle, R. E. and Cummins, K. L. , 2002: The North American Lightning Detection Network (NALDN) – First Results: 1998 – 2000, Monthly Weather Review, Vol. 130, pp. 2098 – 2109.