Analysis of a Heavy Rainfall Episode Focusing on Total Lightning Detection in the Basque Country

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I. INTRODUCTION

This work is centred on the study of a heavy rainfall episode that took place over the Biscay coast in September 2009, with special focus on the data obtained from total lightning detection.

In September 16th 2009, an aisled depression at high levels crossed over the Basque Country following the NW direction. In September 17th it turned back and in September 18th it placed over the Basque Country, moving towards the south of France. This dynamic instability received the contribution from humid air due to the North wind in low layers.

The rainfall in September 18th affected mainly the area of the village of Bermeo, in the Basque Country seaside, close to Cape Matxitxako. The rainfall lasted for hours and left over 228.1 mm of precipitation, with over 50 mm registered in one hour. Other points in the Biscay coastline were also affected by heavy precipitations.

During this episode, total lightning detection was performed using the two lightning detection networks available in the Basque Country. These networks are a LF/VHF network and the LF/VLF sensors of the European network Linet, each of them operating with four sensors in the territory of the Basque Country.

The LF/VHF network reported 269 cloud-to-ground (CG) lightning discharges in a 10 km radius area centred in Bermeo. These locations were performed using the combination of time of arrival (TOA) and magnetic direction finding (MDF) technologies in this network. 263 of these events were time-correlated with a precision of less than one millisecond to the detections performed by the LF/VLF network sensors, which represents a high correlation level.

The rainfall episode could be perfectly monitored by the experts working in meteorological surveillance by using different real-time information systems, such as weather radars, satellite, the automatic weather station network and the two lightning detection networks.

II. DESCRIPTION

This research is focused on the analysis of a heavy rainfall episode from the point of view of lightning detection. By the end of the summer season, many thunderstorms cross over the Basque Country, leaving certainly interesting episodes for research purposes. These thunderstorms sometimes leave behind heavy rains and high levels of electrical activity. This is the case of the episode presented in this paper, which happened on September 18th 2009.

The heavy rainfall episode was due to an aisled depression that crossed over the Basque Country in the previous days, returning to the coast of Biscay and placing over Cape Matxitxako on September 18th 2009. The thunderstorms lasted for many hours, leaving 228 mm of precipitation.

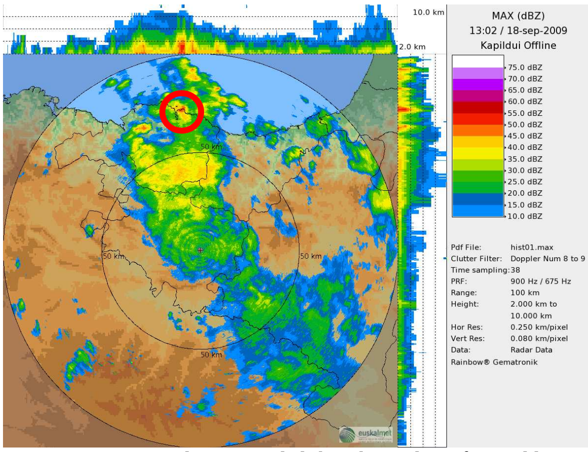

FIG. 1: MAX product provided by the radar of Kapildui on September 18th 2009 at 13:02 UTC.

Fig. 1 presents an example of the precipitation detection performed by the weather radar of Kapildui operated by the Basque Meteorology Agency (EUSKALMET). The area indicated by the red circle represents the location of the villages most affected by the rainfall.

Apart from the analysis of the meteorological conditions that lead to the formation of the heavy rainfall episode over the coast of Biscay and the real time monitoring of the episode using data from the automatic weather station network and the weather radar, this could be one of the first times when total lightning detection could be performed in the Basque Country with the data of two different lightning detection networks.

The electrical activity in the reduced area of the Basque Country (~7000 km^2) can be monitored with a small number of sensors. However, this may lead to inaccuracies due to the failure of one of the sensors in the network. Two lightning detection networks were used in this episode. The first one, composed of four LF/VHF LS8000 sensors (manufactured by Vaisala), began its operation in November 2008 (Gaztelumendi et al. 2009) (López et al. 2010), and by the time of the rainfall episode it was completely operative. The second one consists on four LF/VLF Linet sensors (Betz et al. 2005) that was setup between the months of May and July of 2008. The redundancy introduced by the presence of these two networks is a must for operative reasons, assuring the availability of data even when one of the networks suffers from the failure of one or more sensors.

The use of the LF/VHF network allows the monitoring of both CG events and intra-cloud (IC) VHF radiation sources. The number of these sources is overwhelming in order to be graphically represented, although they were monitored online, as they provide useful information about the different stages of the thunderstorms: initiation, mature stage and decay.

The data available by the Linet network consists of CG impacts and IC events, with an estimation of their altitude. For the research purposes of this work, the attention has been driven into the temporal correlations between the CG impacts detected by the two networks.

III. RESULTS

For the analysis of the lightning detections during the episode under study, a circular area of 10 km radius was set with centre in the village of Bermeo, which was one of the most affected by the rainfalls in that day.

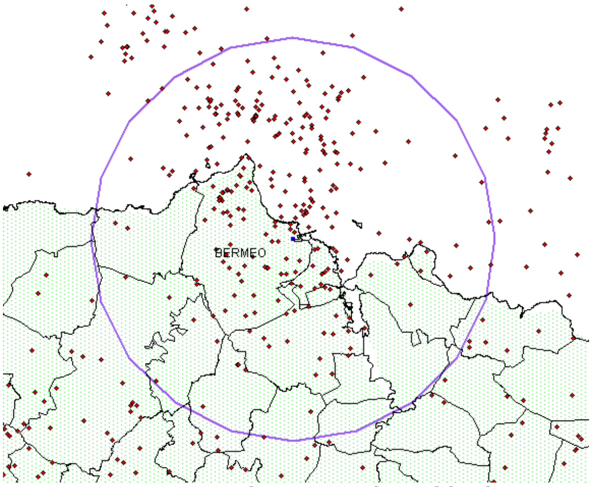

FIG. 2: CG impacts around Bermeo as detected by the LF/VHF network.

Fig. 2 depicts the CG lightning impacts detected by the LF part of the LF/VHF network. The total number of CG impacts represented in the selected area in this picture is 269.

These events have been compared to the events detected by the Linet network. The criteria applied for this comparison has been as follows. An event is time correlated if the time difference between the data reported by the two networks is lees than or equal to one millisecond.

The study of the time correlations shows that 263 out of 269 are correlated with Linet events. This is a very high correlation level between the events detected by the LF/VHF network and those detected by the LF/VLF sensors.

The following picture presents the distribution of the pairs of time correlated events close to the village of Bermeo.

FIG. 3: Pairs of time correlated events close to Bermeo

Correlated pairs are named with a number that assigned accordingly to the time when the event happened.

Considering the 263 correlated events, we can report the following statistics:

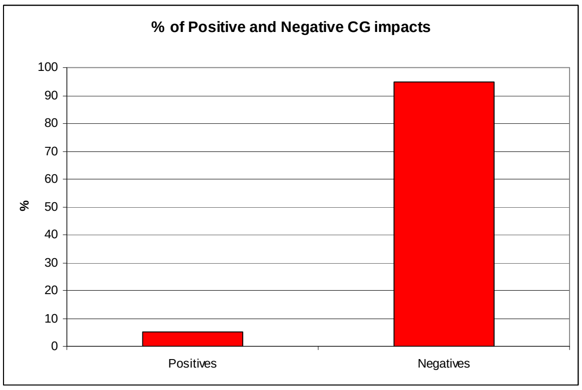

FIG. 4: Distribution of positive and negative CG events detected by the two networks

The percent of positive impacts detected by the VLF network is a little far from the normal values of impacts with this polarity taking into account the warm season in the latitudes of the Basque Country. It should be closer to the distribution given by the LF network, as presented in Fig. 4.

It must be remarked that the VLF network events are both CG and IC. Therefore, LF CG events are time correlated with VLF ICs and CGs. About the 25% of the events detected by the VLF network are IC. This is interesting from the point of view of the two different detection technologies in use. A time correlated event may be detected as IC and CG respectively by the different networks, being the IC a cloud precursor to the CG impact detected by the LF network.

Another interesting data that can be outlined is the confidence area of the CG events detected by the LF network. This parameter represents the most probable area in which the lightning impact may have happened. It is given in terms of the semi-major and semi-minor axes of an elliptical area. The median value of the semi-major axis for the CG events in the study area is one kilometre, which remains acceptable in terms of quality and with respect to the geometry of the network.

As it has been related before, most of the electrical activity affected the specific coastline of Biscay close to Cape Matxitxako and the village of Bermeo. One of the LF/VHF sensor sites is located at Cape Matxitxako. The electrical activity at the site was strong, and as a result of this episode a major failure in the GPS system due to a close lightning impact led to the failure of the LF subsystem.

III. CONCLUSIONS

In this paper a heavy rainfall episode over the coast of the Basque Country. The attention has been focused on lightning detection.

Two different lightning detection networks with three technologies were used for total lightning detection. Previous to this series of thunderstorms, other severe weather episodes had been monitored using the LF/VHF network. That is the case, for example, of the Klaus cyclogenesis (Gaztelumendi et al. 2009). The thunderstorms over the Biscay coastline lasted for hours, and more that 260 cloud to ground lightning impacts were detected and time correlated between the two networks.

The level of correlation acquired, over the 97% of the total number of CG impacts registered by the LF subnetwork, represents a very good quality in the measurements and, therefore, shows that the lightning detection networks installed in the Basque Country perform very well.

These networks have provided a new point of view for meteorologists, people working in weather surveillance and researchers in the Basque Country. Together with the real time information available from the automatic weather station network and other information systems, such as the weather radar, they provide a complete dataset of thunderstorms. Severe weather episodes such as the one related in this paper could be monitored using the lightning detection networks.

The information made available by the networks allows a perfect monitoring of the evolution of thunderstorms in the Basque Country.

IV. ACKNOWLEDGEMENTS

The authors would like to thank the Basque Government and especially the Emergencies and Meteorology Directorate for the public provision of data and for operational service financial support. We also would like to thank all our colleagues from EUSKALMET for their daily effort in promoting valuable services for the Basque community.

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