SIGNATURE OF HAIL PRECIPITATION ON THE GROUND

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I. INTRODUCTION

In describing the hail climatology of one particular study zone, hailpad networks are the most widely used systems for determining the ground truth. In spite of some minor disadvantages, hailpad networks provide very detailed information on a number of hail parameters. These values may subsequently be used to construct databases integrating the parameters obtained separately by each hailpad from both a spatial and temporal perspective. These integrated parameters for one particular study zone are typical of the different areas and may be interpreted as a 'signature' of the characteristics of hailstorms in each area.

This study compares the parameters describing the characteristic features of hail precipitation in the Iberian Peninsula (Province of Zaragoza) and in Argentina (Province of Mendoza) on the basis of data from the corresponding hailpad networks. The maximum values registered have also been computed, as they may be very useful in studies on meteorological risks in engineering. The frequency histograms of the variables have also been computed for the different hailpads and in different time spans. These histograms implement the information obtained from the mean and extreme values and may be very useful in future studies relating this type of variable to thermodynamic parameters or radar variables.

II. STUDY AREAS AND DATABASES

Although different methods have been used since the 1960s to calculate parameters connected with hail, today the most widely used sensor is the hailpad. Different authors (Fraile et al., 1992) have studied the calculation of the variables related to hailstones based on impacts caused by them on the surface of the hailpad. As a result, hailpads allow us to obtain a wide range of characteristic variables of hail precipitation, such as the presence or absence of hail, maximum precipitated size, number of impacts (number of impacts per m^{-2}), total precipitated hail mass (g m^{-2}), total kinetic energy (J m^{-2}), area covered by hail, hail size histograms (N. / size range), parameters of the adjustment to the exponential distribution or gamma, amongst others.

As it is not possible to cover the whole of a geographic area with hailpads, these are usually installed over a small, localised area. The area and density of a hailpad network is established based on the characteristics of the hailstorms that affect the respective regions, as well as the limitations in terms of maintaining the network. The main limitation of these networks is the overlapping of two different hailstorms on the same pad. To avoid this, it is necessary to have an effective methodology available for checking and replacing pads on which hail has fallen during the experimental data gathering campaigns. In our case, in the study zones selected, the weather radars include an application developed by López and Sánchez (2009a) which shows directly on a screen the probability of hail on each hailpad in the network, making it possible to minimise the replacement times of the pads and avoiding overlap errors.

As already mentioned, in order to carry out this study, data was gathered and analysed on hail from the hailpad networks in the province of Zaragoza (Spain) and the province of Mendoza (Argentina). These are two geographically distant zones, but which share a common characteristic: a high frequency of storms with hail precipitation, mainly during the summer months (Sánchez et al., 2009b)

Firstly, in Spain there is a hailpad network in Zaragoza. The study zone is in the extreme north-east of the Iberian Peninsula, and covers an area of some 50,000 km^2. The network of hailpads in Zaragoza is located in the south-west of the province, in the districts of Valdejalón, the Community of Calatayud, Campo de Cariñena and Campo de Daroca, as well as the northern part of the district of Jiloca in the province of Teruel. The 100 hailpads in the network are distributed along the vertices of a grid measuring 5 x 5 km, coinciding with the UTM network. Five experimental campaigns were carried out to gather data in this area from 2003 to 2007. A total of 413 hailpads included in the study received impacts.

Secondly, the Argentinean province of Mendoza is located between 32° and 37° latitude S and 67° and 70° longitude W, to the west of Argentina on the border with Chile. In this study a network of hailpads located in the south of the province was used, with 130 pads distributed in a 5 x 5 km grid. In the areas with the highest storm frequency, the network is supported by another internal grid measuring 2.5 x 2.5 km. The network has data from three experimental campaigns carried out between 2005 and 2007. A total of 750 hailpads in the area received impacts.

III. RESULTS AND DISCUSSION

Firstly, in order to arrive at an approximation of the intensity of hail precipitation in the area of the hailpads, the descriptive statistics were calculated (maximum, minimum and mean values, and standard deviation) of the variables of the hailpads for the individual pads. The results are shown in Tables I and II.

The variables measured in the hailpads make it possible to characterise the hail precipitation in each of the networks. In terms of the variables per unit of surface, if we compare the two study areas, the maximum number of impacts is quite similar in both networks (9222 impacts m^{-2} in Zaragoza, compared to 9924 impacts m^{-2} in Mendoza); however, the maximum kinetic energy per unit of surface is more than three times higher in Argentina than in Spain.

	Nº impacts (imp m^{-2})	Mass (g m^{-2})	Kinetic energy (J m^{-2})	Maximum diameter (mm)
Maximum	9222	4007.05	819.97	43.4
Minimum	9	0.02	0.03	5.4
Mean	938	380.99	44.11	13.5
Stand.Dev.	1417	705.62	102.04	6.3

TABLE I: Characteristic values per hailpad in Zaragoza.

	Nº impacts (imp m^{-2})	Mass (g m^{-2})	Kinetic energy (J m^{-2})	Maximum diameter (mm)
Maximum	9924	8712.59	2588.32	49.5
Minimum	10	0.69	0.03	5.4
Mean	872	516.36	79.89	16.5
Stand.Dev.	1150	1044.74	231.10	7.7

TABLE II: Characteristic values per hailpad in Mendoza.

Also, in Zaragoza and with respect to the mass of ice precipitated per unit of surface, a fall of little more than 4 kg m^{-2} was recorded on a hail pad, with the mean being nearly 381 g m-2. In Mendoza these results are nearly twice as high: a maximum of 8.7 kg m^{-2}, with means of 516.36 g m^{-2}). This data may be applicable to engineering studies to calculate the maximum load to be supported by specific types of structures (roofs, canopies, etc.).

Furthermore, the maximum diameter recorded on a hailpad was 4.3 cm in Zaragoza, compared to 4.9 cm in Mendoza.

This study also estimated the mean ice mass precipitated per day, which was 6.73 10^4 tons for the network in Zaragoza, with a maximum of 5.56 10^5 tons. If we suppose that a normal storm in the area has dimensions of 20 x 10 x 10 km, or a volume of 2000 km^3, and that the normal liquid water content in a storm is 2 g m^{-3}, the liquid water contained in this volume would be 4 10^{12} g, or 4 10^6 tons. Out of these, they only precipitate a mean of some 7 10^4 tons in the form of ice, or only 1 or 2 % of the liquid water content of a storm.

The numerical data shown above in Tables I and II make it possible to understand the characteristics of the hail precipitation, although it would be necessary to know if these values are the most usual, or if otherwise they are extreme cases. As a result, the frequency histograms were calculated of the values of the hailpad variables (number, mass, energy and size) recorded on each pad and accumulated by days. For example, Figure 1 and 2 show the maximum diameter frequency histograms recorded for Zaragoza and Mendoza respectively.

For both networks, the histograms show how the values of the smallest classes of number of impacts, precipitated ice mass and kinetic energy per unit of surface are more frequent than the larger classes. The frequency histograms for both networks show that the modes are found in the values of the lowest intervals, meaning that the most frequently observed values are found within the smaller classes, with the maximum and mean values shown in tables I and II higher than the most usual values.

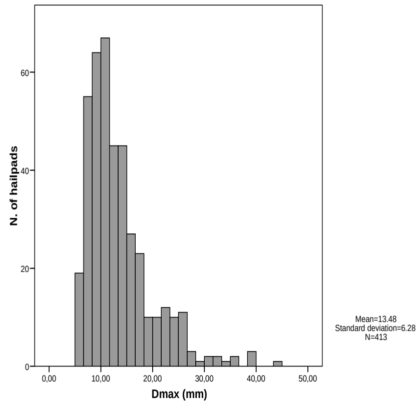

FIG. 1: Histogram of diameter frequencies in Zaragoza

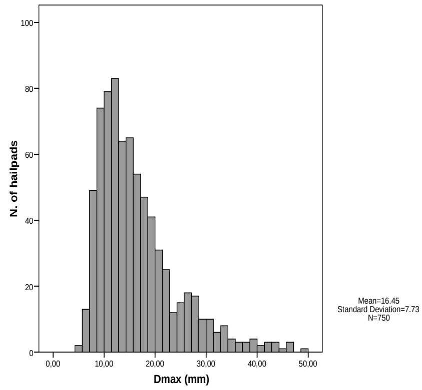

FIG. 1: Histogram of diameter frequencies in Mendoza

In terms of maximum diameter recorded on each pad, the most frequent value, the mode, is between 10 and 12 mm in Zaragoza, while the daily maximum varies between 13 and 16 mm. Unlike the previous variables, the mode of the maximum diameter is not observed in the smallest classes. The same occurs with the network in Argentina, which has a mode of between 12 and 15 mm, while the daily maximum varies between 15 and 18 mm. Finally, on representing the accumulated percentage of the frequency of the maximum diameter for each pad or for each day, it may be seen that 75% of the pads have a maximum diameter of less than 15 mm in Zaragoza, and 20 mm in Mendoza.

IV. ACKNOWLEDGMENTS

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