RADAR PARAMETERS DETERMINING THE KINETIC ENERGY OF HAIL PRECIPITATION IN THE IBERIAN PENINSULA

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I. INTRODUCTION AND MOTIVE OF THE STUDY

Detecting the hail precipitation generated by a particular storm is a difficult task because of the limited area usually affected by hail and due to the irregularity of hail falls on the ground with respect to time and space. Some of the methods most frequently used to establish hail climatologies are networks of observers and hailpad networks. Both methods have disadvantages, especially when the study zone is large and the cost of maintaining a network is high.

In an attempt to overcome these difficulties, a number of studies have developed models that detect hail precipitation by means of meteorological radar systems. Some of these models make use of discriminatory statistical techniques that achieve very satisfactory results combining several radar parameters (López & Sánchez, 2009a). Moreover, it would be very interesting to determine not only the likelihood of hail, but also some of the characteristics of the hailstones, such as their number or their kinetic energy, as these parameters are closely related to the damage which hail causes to infrastructures and/or crops.

The aim of this study is to analyze in depth the relationship between the kinetic energy of hail and a number of radar parameters. A few studies have been devoted to the relationship between energy and reflectivity, but a Principal Components Analysis has revealed that other radar parameters must also be considered to obtain a more accurate description of the kinetic energy of the hailstones that hit the ground if better nowcasting models are to be constructed. The detection of these relationships in this paper is a first step to determine the necessary ingredients to set up a model for forecasting the kinetic energy of hail.

II. STUDY AREAS AND DATABASES

The study areas selected were in the province of Zaragoza (Spain) and in the province of Mendoza (Argentina). Both share a high frequency of summer storms with precipitation in the form of hail (Sánchez et al., 2009b). Also, both have networks of hailpads and weather radar systems that cover the whole of the networks. The province of Zaragoza, in the north-east of the Iberian Peninsula, has a network of 100 hailpads. The Argentinean province of Mendoza, close to the Andes range on the border with Chile, also has a network of 130 hailpads with an identical grid size. As already mentioned, both zones have weather radars: in Zaragoza there is a C-band radar that belongs to the University of León, and in Mendoza there is an S-band radar which belongs to the provincial government of Mendoza. Both radars have the application developed by López and Sánchez (2009a) which makes it possible to view on the screen, in real-time, the area affected by the hail precipitation. Also, using the TITAN software it is possible to obtain different radar parameters for each storm cell with precipitation (Dixon and Wiener, 1993).

Based on this experimental set-up, it is possible to create integrated databases, on the one hand, providing us with characteristic data on the storm that is generating hail precipitation, and on the other, providing us with details on the characteristics of the precipitation at that moment through the variables obtained from the hailpads. In our case, we have focused our attention especially on the characteristic kinetic energy of the precipitation.

However, not all of the hailpads receiving impacts were included in the study. From the initial database, which related all of the hailpads that received impacts with a series of radar parameters, we selected the hailpads without problems connected with screening, reading, etc. As a result, by applying this methodology the database from Zaragoza, which originally consisted of 235 hailpads, finally included a total of 119. Similarly, the final database from Mendoza used in this study included a total of 100 hailpads, out of an original total of 399.

III. RESULTS

The aim of the first part of the study was to calculate an empirical relation between the *total kinetic energy* measured in each hailpad (Ke) from Zaragoza, and the reflectivity measured through the C-band weather radar covering this network. A simple linear regression was applied to the two variables. The results provide linear equations, whose explained variance is only 0.230. Neither is this percentage significant for Mendoza.

In the light of these results, a detailed analysis was then carried out of the relations that existed between the energy values of hail on the ground and the different radar parameters. The aim was to discover if it would be possible to reach higher percentages of explained variance by including the new variables. To do so, we firstly studied the correlations between the Ke and the radar parameters. The results of the analysis revealed that in the case of Zaragoza, the variables which have significant Pearson correlations at level 0.01 are the *specific reflectivity* ($mm^6\ mm^3$), the accumulated *VIL* during the storm ($kg\ m^{-2}$), the *pondered centroid height in reflectivity* (km) and the *maximum reflectivity height* (km). It also has a significant correlation at level 0.05 with the *specific VIL* ($kg\ m^{-2}$), with the *centroid height* (km) and with the *top* (km). In the case of Mendoza, a higher number of significant correlations were obtained than in Zaragoza, with higher correlation coefficients.

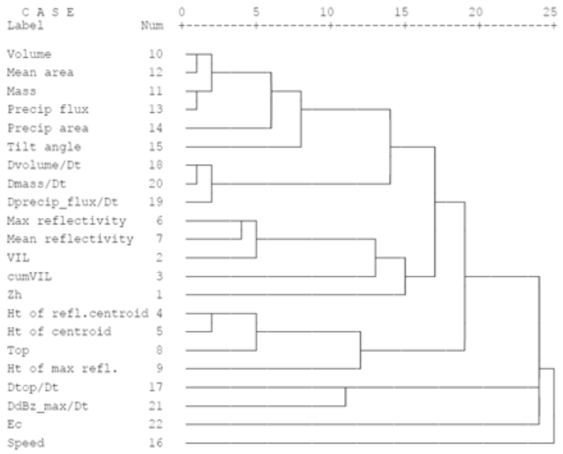

FIGURE 1: Dendogram obtained from the *cluster analysis*.

A cluster analysis was then carried out for each of the integrated databases (radar variables and Ke). The results of the analysis for Zaragoza are shown in Fig. 1. In the case of Mendoza, these groups are less hierarchized. It is highly significant to note that through the cluster analysis in both areas, four *groups of radar variables* are established, namely: *physical dimensions of the storm, progress in time, vertical structure* and *microphysics.* The four groups obtained can be interpreted in meteorological terms as necessary "ingredients" in order to explain the variance found in the kinetic energy recorded in hail precipitation on the ground.

	1	2	3	4
% σ^2	45.631	61.607	73.326	80.084
Parameters	Volume	Dtop/Dt	Ht of refl. centroid	Zh
	Mass	Dvolume/Dt	Ht of centroid	VIL
	Mean area	Dprecip_flux/Dt	Top	cumVIL
	Precip flux	Dmass/Dt	Ht of max reflectivity	Max reflect.
	Precip area	DdBz_max/Dt		Mean reflect.
	Tilt angle			

TABLE I: Summary of the results obtained in the Principal Components Analysis.

Finally, a Principal Components Analysis was carried out, with Kaiser's Varimax rotation. In the case of the network in Zaragoza, the 4 main components extracted precisely reflect the groups formed in the cluster analysis (See Table I). The component that provides most of the explained variance is that formed by the variables connected with the *physical dimensions of the storm*, followed by the *progress in time*, the *vertical structure*, and finally the amount of water available. With these four components it is possible to explain 80.084% of the accumulated variance.

In turn, in the Argentinean network the five principal components that were extracted combine parameters from different groups. In the network from Mendoza, the most important variables were those in relation to the *amount of water available* and the *vertical structure* (associated with the kinetic energy measured by the hailpad), and secondly the variables referring to the *dimensions of the storm* and the *progress in time*. As a result, we once again see that a high percentage of explained variance (81.531%) is achieved with the components that were extracted.

IV. CONCLUSIONS

- The simple relations between the *kinetic energy* measured by the hailpad and the *maximum specific reflectivity* on the same measured by weather radar do not provide satisfactory results in terms of the percentage of explained variance.

- To increase the explained variance (to thresholds of approximately 80%), it is necessary to include radar parameters in the predictive models of the Ke that are representative of at least four *groups of variables.* The four *groups of variables* found in the two study areas through the cluster analysis and Principal Components Analysis are: *physical dimensions of the storm, progress in time, vertical structure* and *microphysics*. Each of the groups has different radar parameters associated with it, and is susceptible to being interpreted from a meteorological perspective.

- Detecting these relations is the first step in constructing a model for the prediction of kinetic energy on the ground using radar data. In fact, the results obtained in this sense indicate how, with strictly statistical criteria, the construction of regression models using the stepwise method points towards equations composed of radar parameters included in the different *groups of variables* found.

V. ACKNOWLEDGMENTS

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VI. REFERENCES

Dixon M. and Wiener, G., 1993: TITAN: Thunderstorm, Identification, Tracking, Analysis and Nowcasting –A radar based Methodology. *J. Atmos. Oceanic Technol*., 10 785 – 797.

López L. and Sánchez J.L., 2009a: . Discriminant methods for radar detection of hail. *Atmos. Res*., 93 358-368

Sánchez J.L., Marcos J.L., Dessens J., López L., Bustos C and García-Ortega E., 2009b: Assessing sounding-derived parameters as storm predictors in diferent latitudes. *Atmos. Res*., 93 446-456.