SHORT-TERM FORECAST OF HAIL PRECIPITATION PARAMETERS

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I. INTRODUCTION

An important number of studies have developed short-term statistical models that make use of data on pre-convective conditions to determine the risk of storms with hail precipitation in a particular study zone. The experience of the Group for Atmospheric Physics at the University of León, Spain, has shown that it is more adequate to begin the process by selecting those variables that are the best forecasters and then combine them using discriminatory or logistical functions (López et al., 2007; Sánchez et al., 2008, 2009).

Based on previous experience, the aim of this study is the selection of the most adequate meteorological variables to be included in statistical short-term forecast models of the characteristics of hail, namely the values of the following variables per m^{-2}: number of hailstones, kinetic energy, ice mass and maximum diameter have been determined in relation to the pre-convective conditions.

The first step was to analyse the relations between the values of the 4 variables that characterize the maximum hail precipitation expected and the meteorological variables obtained from the closest sounding stations.

II. STUDY ZONE

Three study zones were selected, characterised by having a high frequency of hailstorms, the availability of networks of hailpads in these areas, and the existence of data from radiosondes close to these areas.

The first study zone is located in the Ebro Valley in the northeast of the Iberian Peninsula, which covers an area of approximately 50,000 km^2. The Group for Atmospheric Physics at the University of León has been carrying out summer campaigns in this area gathering data for detailed studies on the characteristics of hailstorms. The detection and calculation of the parameters related to hail precipitation is carried out using an extensive network of hailpads covering an area of 2,700 km^2. In this zone, the characterization of the atmospheric conditions was carried out using data from a sounding balloon launched at 00 UTC or 12 UTC in the city of Zaragoza, in the middle of the study zone. To set up the study, 38 days were used with complete databases. These days corresponded to the months of June to September from 2003 to 2007.

The second study area comprises the north and centre of the Argentinean province of Mendoza, at the foot of the Andes. This study zone is one of the areas in the world most affected by severe convective phenomena. In the zone, the provincial government has a network of 130 hailpads covering a representative area of 5x5 km each one. The characterization of the meteorological conditions was also carried out by means of radiosondes launched from the city of Cruz Negra. The radiosondes were launched at 15 UTC. A total of 44 days were analysed.

Finally, the third study zone is located in France, where in the period between 1999 and 2003, insurance companies paid an average of 170 million € per year in compensation for crops affected by hail. One third of the damage to crops due to hail is concentrated in the south-west (region of Aquitaine et Midi-Pyrénées), another third in the south-east, and the rest, all over the other regions of the country. In these regions, the ANELFA (*Association Nationale d'Etude et de Lutte contre les Fléaux Atmosphériques*) has installed a dense network with over 1,000 hailpads. Sounding data were available for the study from 46 daily soundings launched at 12 UTC in the city of Bordeaux. In these days, hail precipitation was registered in the French hailpad network between the years 1997 and 2005.

III. DATA BASES AND METHODOLOGY

For each of the zones, integrated databases were created including, on the one hand, the characteristic parameters of the hailstorms taken from the hailpads (number of hailstones, kinetic energy, ice mass and maximum diameter) and, on the other, a series of meteorological variables and indices (36 in total) based on the data from the radiosondes. It should be noted that previous studies existed for the three areas, as different discriminating models had already been designed for predicting hailstorms in them (López et al., 2007; Sánchez et al., 2009). In terms of selecting the indices, this experience was of great help. As a result, the indices used were the same used in previous studies.

For each of the days, individual data were available (per m^2) from hailpads affected by hail: number of hailstones (N), kinetic energy (E), ice mass (M) and maximum diameter (D). However, and with the aim of correlating these data with the daily data from the radiosondes, different methods for the daily integration of these data were calculated. As a result, we obtained the maximum daily values for each of these variables, the accumulated daily values (except for the size), and also the values recorded in the hailpad that presented the maximum kinetic energy. The aim was to discover which of these parameters (N, E, M or D) and through which daily integration (maximum values, accumulated, or the hailpad with maximum energy) had the best correlations with the indices that characterised the pre-convective conditions. This way, the results revealed which of these parameters are the most suitable, a priori, for developing prediction models for the characteristics of hail precipitation on the ground.

Subsequently, with the same objective in mind, a Principal Components Analysis was carried out, together with a Varimax rotation with Kaiser normalisation of all of the variables for each of the zones. The relations obtained between the different variables were analysed in detail, and interpreted in meteorological terms.

IV. RESULTS AND DISCUSSION

We should not forget that the three zones do not have exactly the same characteristics in relation to hail precipitation, especially in terms of the maximum values and frequency histograms. For example, the parameters obtained in Argentina, particularly with regard to energy and maximum diameter, are higher than in the others. The pre-convective conditions that exist in situations with hailstorms are also different (Sánchez et al., 2009). For this reason we decided to analyse the results individually for each of the areas.

Zaragoza (Spain)	**Mendoza (Argentina)**	**Bordeaux (France)**
EHI	EHI	850 hPa dew point
VGP	VGP	Lifted Index
850 hPa dew point	Wind 500 hPa	WBZ
Showalter Index		0 ºC altitude
		Tropopause height
		Convective temperature
		CAP

TABLE I. Summary of the significant correlations found for the maximum diameter.

Firstly, Pearson’s correlation coefficients were calculated, based on the daily data from the hailpads and the daily data from the radiosondes. Table I shows a summary of the significant correlations (at a significance level of 0.01) found for the maximum diameter for each of the zones. In the case of Zaragoza, the results reveal that the maximum diameter recorded by a hailpad is correlated with the dew point at 850 hPa, the Showalter index, the VGP and the EHI. This is coherent with the results found by Sánchez et al. (2008), who constructed a logistical equation in order to integrate the prediction models for storms based on radiosonde variables for four different areas. They found that the Showalter index and the dew point at 850 hPa are the variables that best characterise pre-convective situations, regardless of the study area. These two indices have now also been found to be important in order to predict the maximum diameter. The correlations found for the maximum energy in the zone show that this is significantly correlated with the dew point at 850hPa and the VGP.

In Argentina, the results once again reveal that the maximum diameter has the highest number of significant relations. Once again, the EHI and VGP parameters are significant, together with the wind at 500hPa. The maximum energy in the zone does not have any significant correlations, although the total accumulated energy does, which is correlated with the wind at 500 hPa. This data shows that attempting to construct a prediction model for the maximum energy in the zone would not provide us with satisfactory results, and we would instead have to turn to the daily accumulated energy, or preferably for the prediction of the maximum diameter.

In France, the maximum diameter has significant correlations with up to 7 different parameters, as shown in Table 1. It is especially interesting to note that in the zone neither the VGP index nor the EHI have significant correlations. Also, on analysing the energy data (both maximum and total), we now see the greater importance of parameters related to the vertical atmospheric stratification, such as the tropopause height, the isozero height or the altitude of the CCL.

In terms of the mass and number of impacts, a very low number of correlations were found, especially in France, meaning that their prediction is not easy in any of the areas. However, these parameters are not so closely connected with the damage produced by hail as the energy or maximum diameter, meaning that their prediction is of secondary importance.

Also, the Principal Components Analysis (PCA) shows once again that Zaragoza and Argentina seem to show a similar type of behaviour. The maximum diameter in the two zones is connected in the first components with the indices VGP and EHI, which have proved to be essential in predicting the maximum hail size. However, in France, the maximum diameter is in the fourth principal component, connected with parameters that essentially measure the vertical atmospheric stratification (CCL height, LFC height). As a result, we may see that the results require a specific meteorological interpretation for each of the areas (Zaragoza and Mendoza on the one hand, and France on the other), in terms of the mechanisms behind the formation of hailstorms.

Finally, we believe that the results obtained will make it possible to develop discriminatory prediction models for the hail characteristics in each of the zones. As a result, in Zaragoza and France, the aim will be to develop prediction models for both the diameter and the energy (maximum or accumulated), while in Argentina the studies will focus exclusively on the prediction of maximum diameters.

V. ACKNOWLEDGMENTS

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VI. REFERENCES

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