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Forecasting hailfall using parameters for convective cells identified by radar

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ABSTRACT

The main goal of the present paper is to propose some new criteria that will improve the diagnosis for hail at the surface in real-time, so that they can be applied to surveillance tasks and for nowcasting purposes. The criteria are based on a better knowledge of convective cells that produce hail during their life cycle and better distinguishing between these cells and cells that do not produce hail on the surface. The work focused on a region in the northeast of the Iberian Peninsula, selecting hail events that occurred in the 2004–2012 period and using the information provided by the Meteorological Service of Catalonia's weather radar network. The methodology deals with the analysis of the level of reflectivity associated with the maximum values, which can be considered as the core of the convective vertical development. The chosen radar parameters are operative and they take into consideration the following: the reflectivity, the vertically integrated liquid, the highest altitude at which radar echoes have been observed over a determined reflectivity threshold, as well as the direction and the duration of the convective cells. This work aims to complement all the previous work carried out by different authors, in order to better identify hail in the chosen region.

1. Introduction

The Ebro River Basin, in the western plain of Catalonia, is one of the most hail-affected areas in Europe (Merino et al., 2013; Tuovinen et al., 2009; Počakal et al., 2009; Berthet et al, 2013; Webb et al., 2009). Almost every year, two or three events with large hail (hail diameter over 2 cm) occur. This danger is aggravated by the fact that the economy of the region is essentially related to agricultural production, consisting mainly of fruit trees, which results in further vulnerability. Consequently, hail on the surface constitutes, on average, a greater risk in the region. Because of this, several previous studies have proposed different methodologies to identify and diagnose hail in the region (Aran et al., 2007; Ceperuelo et al., 2009; López and Sánchez, 2009; Palencia et al., 2010; García-Ortega et al., 2012; Farnell and Llasat, 2013; Merino et al., 2014), and there has also been a focus on a meteorological analysis of certain specific episodes (Farnell et al., 2009; Pineda et al., 2009; Ceperuelo et al., 2006; Ramis et al., 1997).

Within the methodologies for hail detection in thunderstorms using meteorological radar, there are many different techniques, such as the use of VIL (vertical integrated liquid), the difference between the MLT (melting level) and the maximum height where reflectivity echoes of 45 dBZ are detected (TOP45) (see Donavon and Jungbluth, 2007; Delobbe and Holleman, 2006). Accordingly, it has been proven that thunderstorms in which values of TOP50 were detected above a 20 °C isoline caused the largest hail stones (Betschart and Hering, 2012; Delobbe and Holleman, 2006). Other techniques for hail detection include using discriminant analysis methods, such as principal components analysis (PCA), to improve thresholds and/or equations to allow for better results in hail diagnosis (Ceperuelo et al., 2009; López and Sánchez, 2009). Furthermore, there are other algorithms that focus on the features of convective cells identified using these methods, such as Johnson et al. (1998), Dixon and Wiener (1993), and Rigo et al. (2010).

From the previous bibliography, it seems increasingly clear that the future lies in a combination of more than one variable in order to obtain new parameters to get better information about different aspects of a thunderstorm. These parameters include, for example, the vertical distribution of radar reflectivity, the physical dimensions, the melting parameters, the stage in the life cycle, and the reflectivity. In this sense, this paper deals with applying radar products to improve the identification of hail events in real-time, both for surveillance tasks and for short-time forecasting purposes. It uses the methodology for the identification, characterization, tracking, and nowcasting of convective cells presented in Rigo and Llasat (2004) as a started point and was modified to run in the Meteorological Service of Catalonia (SMC) including new information such as lightning data (Rigo et al., 2010). The technique consists of choosing the regions with the radar volumes associated with maximum reflectivity values, which can be considered as the core of convective vertical development. This methodology

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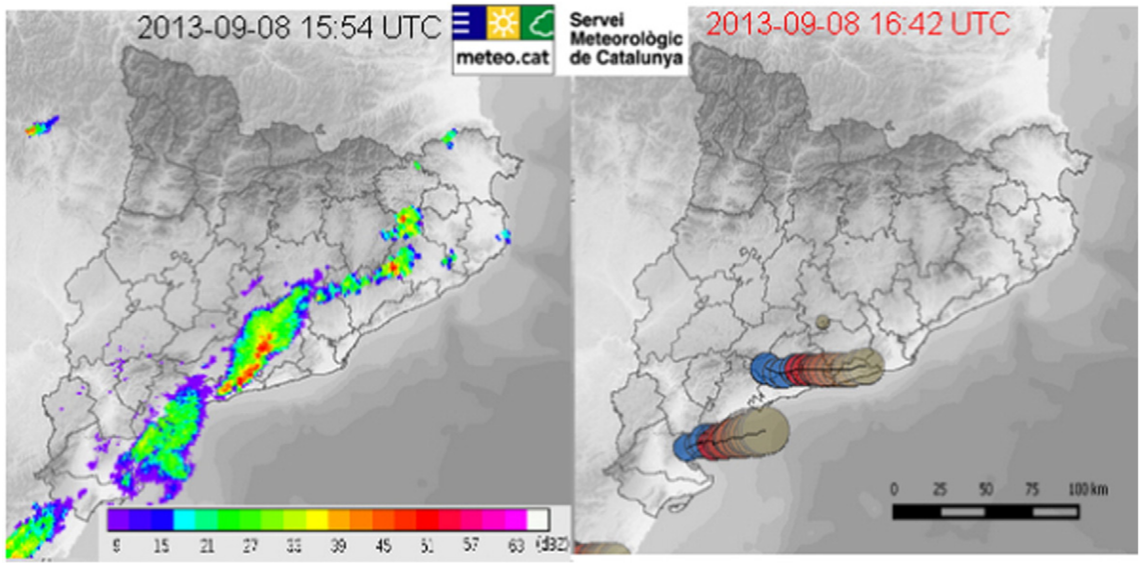

Fig. 1. Example of the operative tool used for nowcasting convection at the Meteorological Service of Catalonia. Left: reflectivity chart at 15:54 UTC on 8 September 2013. Right: past trajectories (in blue), present position (in red), and forecasted trajectory (orange and brown) for the next 48 minutes. The time step between each circle is 6 minutes.

makes it possible to know the stage in the life cycle of a thunderstorm, according to the evolution of certain parameters (Fig. 1). In short, the algorithm identifies convective cells associated to the volumetric cores of maximum reflectivity. The technique tracks the cell for the last 60 minutes before its current position and nowcasts its future trajectory for the next hour by extrapolating the previous tracking details, as well as any increase or decrease in size, using a simple life cycle model. However, until now, this technique has only been applied to identify the possibility of hail on the surface, but it had not been used for hail nowcasting. In this paper, a new methodology has been developed using the philosophy for analyzing the life cycle of convective cells and combining five operative radar products (surface reflectivity, maximum reflectivity in the column, VIL –vertical integrated liquid – TOP30 and TOP50 – and maximum height reached by radar echoes taking into account the reflectivity thresholds of 30 and 50 dBZ, respectively). Unlike in Ceperuelo et al. (2006), the parameters used in this paper do not require a complex calculation and are obtained directly from the radar volumes.

The paper is divided into the following sections: first of all, the different observation systems and the area of study are presented. Then, the hail database and its main climatic features are introduced. The paper then details the proposal of the new methodology to improve hail size identification, and finally, the results and conclusions are shown.

2. Area of study and database

The western part of the Central Depression of Catalonia (Fig. 2), a region known as the Lleida Plain, is bordered by the Ebro Valley to the west, and by different mountain ranges at the rest of the compass points. The difference in altitude between those systems (1000–1700 MASL) and the center of the plain (nearly 100 MASL) creates an important barrier for thunderstorms that started in the Ebro Valley (especially in the area close to the Iberian System mountain range). Usually, when these thunderstorms arrive in the area of study (hereafter, AoS), they have reached the mature phase of their life cycle. Consequently, the intensities are between moderate and high, and mostly in a solid phase, but also potentially liquid.

A quick analysis of the hail events database and the bibliography revealed some climatic aspects that must be taken into account. Firstly, the months of maximum hail activity are May to September, which is similar to other European regions, such as south-west France, Croatia, Finland, and Great Britain. Furthermore, the time of day when the maximum peak of hail activity takes place is at 17 UTC in the Ebro Valley (like in Croatia), while in other European areas, the time of the maximum peak is less well-defined. Finally, the most common values of maximum hail size are generally under 2 cm, but this threshold was exceeded by 12% over the total events analyzed.

Due to the high hail risk for the agriculture, a network of hailpads was installed at the beginning of the 21st century (Sánchez et al., 2009). The network comprises 174 hailpads distributed in a more or less regular grid of 4×4 km^2 (Fig. 2). It is managed by the University of Leon (ULe) and the Vegetation Protection Association of the “Terres de Ponent” (ADV). Although the resolution of the hailpad network is larger than for radar products (1×1 or 2×2 km^2), it is good enough (Dye and Martner, 1978; Long, 1980; Dalezios et al, 2002) to associate hail observations with convective cells (which have generally diameters between 5 and 15 km). During the period when hail most frequently falls (April to September), the data were recorded and analyzed after each storm. The size distribution, among other variables, was then determined. This means that the network allows hail events and the size distribution estimated by the radar observations to be confirmed. The parameter selected in the present paper has been the maximum hail diameter, which is a magnitude that can be easily compared with direct observations. The specific area where the hailpad information is available (Fig. 2), and that is included in the AoS, will be referred to herein as the region of interest (hereafter, RoI).

On the other hand, the Meteorological Service of Catalonia (SMC) has developed a C-band radar network that covers the entire territory with a spatial resolution of 1×1 km^2. Two of the radars are located quite close to the selected region (Fig. 2): La Panadella (hereafter, CDV) and Tivissa-Llaberia (hereafter, LMI). Table 1 shows the main features of both radars in terms of the present paper.

The radar products used in the analysis run every 6 minutes, and they have the following compositions: CAPPI volumes with 10 levels (between 1 and 10 km above sea level), VIL (vertical integrated liquid), TOP30 (maximum altitude of echoes that reach or exceed 30 dBZ), and TOP50 (similar to TOP30, but for the 50 dBZ threshold, useful for identifying deep convection). Because of the availability of the radar data and the information from the hailpads network, the chosen period goes from 2004 to 2012, including only the months when hail falls: