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Hailstorms in southwestern France: Incidence and atmospheric characterization

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ABSTRACT

The characterization of atmospheric conditions at different scales and their relationships to meteorological phenomena is a basic tool for improving the understanding and prediction of severe atmospheric events. Hailstorms are relatively common in southern Europe during summer, causing significant adverse impacts to property and infrastructure. This paper provides a spatiotemporal characterization of hail falls in southwestern France between 2000 and 2010, using the hail pad network operated there by the Association Nationale d'Etude et de Lutte contre les Fléaux Atmosphériques (ANELFA). This area is greatly affected by hailstorms. It was observed that the greatest incidence and severity of hail was in the central Pyrenees during May and July, with decreasing frequency and intensity toward the Atlantic coast. We selected 100 events in which severe hailstorms were reported, to study atmospheric parameters responsible for their occurrence. We performed mesoscale simulations with the WRF model, using parameterizations and fields reported in previous studies. By applying principal component analysis (PCA) and cluster analysis, we obtained three configurations to help establish relationships with the spatiotemporal incidence of hailstorms. The method and results obtained improve knowledge of the conditions favorable for hailstorms in southwestern France. This allows better hail prediction by relating atmospheric conditions with characteristics of hail precipitation on the ground.

Contents

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1. Introduction

Hailstorms are phenomena frequently associated with severe convection at mid latitudes (Eccel et al., 2012). Sioutas et al. (2009) determined areas in both hemispheres of more frequent hailstorms. In Europe, such areas included the northern Iberian Peninsula, central Europe and northern Balkans. Damage from hail falls has increased in the last two decades across various regions of Europe. In France, there has been a 70% increase in hail intensity (assessed by kinetic energy) between 1989 and 2009, although the frequency has not changed significantly over this period (Berthet et al., 2011).

The main challenges associated with the study of hail precipitation are its identification and prediction. The difficulty in overcoming these challenges lies with the small spatial and temporal scales on which hailstorms develop (García-Ortega et al., 2012), necessitating costly and dense observation networks to provide quantitative measurements. An alternative approach is to estimate hailstorm occurrence by establishing relationships between well-observed meteorological variables (Merino et al., 2013). In recent years, numerous techniques have been used to improve identification of related phenomena: damage observations (Vinet, 2001), hail pad networks (Sanchez et al., 2009; Pocakal, 2011), vertical profiles using numerical weather prediction (NWP) models (Hand and Cappelluti, 2011), radar images (López and Sánchez, 2009), and multispectral satellite data (Cecil and Blankenship, 2012).

One of the influential aspects in hailstorm development is topography. Numerous studies demonstrate a high frequency of hail falls in areas with complex terrain. Vinet (2001) found that hail damage tended to be more severe on the leeward slopes of mountain ranges. This is consistent with similar observations in Macedonia (Sioutas et al., 2005) and Spain (García-Ortega et al., 2012).

Numerical simulation is one of the best tools for the analysis of atmospheric conditions under which hailstorms develop. Nevertheless, current NWP models have high uncertainty in predicting hail falls and intensity (Brimelow et al., 2002). For this reason, atmospheric variables and thermodynamic indices continue to be used for characterizing convective environments and studying relationships at different scales (López et al., 2007; Merino et al., 2013). If convective instability and humidity flux convergence are sufficient (García-Ortega et al., 2012), convection can be triggered by a combination of factors such as updrafts produced in frontal situations, daytime solar heating, or orographic lifting (Johns and Doswell, 1992).

Preconvective environments have traditionally been characterized by a thermodynamic instability index, determined from radiosondes or profiles obtained via numerical models (Huntrieser et al., 1997; Haklander and van Delden, 2003; Manzato, 2003; Doswell and Schultz, 2006; Sánchez et al., 2008; Kaltenböck et al., 2009). Convective Available Potential Energy (CAPE; Moncrieff and Miller, 1976) is a major parameter for severe convection (Doswell and Bosart, 2001), although it may not be representative in frontal situations (Berthet et al., 2013). In addition, the Showalter index (SI; Showalter, 1953; Hart and Korotky, 1991) is used to predict storms in Europe, with hailstorm values approaching −1 (Huntrieser et al., 1997; Kaltenböck et al., 2009). However, there are many factors that cannot be analyzed based on instability indices but are of great importance in the formation of hailstones, as well as other factors that explain the triggering of convection. In addition, the low temporal resolution of radiosonde data for pre-convective environments (Merino et al., 2013; Brimelow et al., 2006) and the impossibility of determining the triggering factors of convection necessitate analysis of different atmospheric variables.

At present, the study of atmospheric patterns, climatology, persistence and geomorphological features remains fundamental to hailstorm prediction. García-Ortega et al. (2011) studied the synoptic patterns on hailstorm days in northeastern Spain. They found that a clear relationship could not be established between synoptic conditions and the spatial distribution of hail precipitation. Thus, it was concluded that investigation at synoptic scale did not permit determination of factors responsible for triggering severe convection, and that future mesoscale analyses were needed. Berthet et al. (2013) reached this same conclusion studying the synoptic environments of 12 severe hailstorm events in France. These events were classified into 3 synoptic types, according to wind and 500 hPa geopotential height. The most frequent type corresponds to low pressure over the western Iberian Peninsula, which produces southwest flow over southwest France. The other two types of synoptic situation are less common. The first corresponds to a trough over the Atlantic Ocean, and the second to a low over the western Mediterranean.

Using numerical simulation, Merino et al. (2013) proposed a method for improving hail fall prediction by combined study of synoptic conditions, mesoscale configurations that are strongly influenced by topography, and hail prediction parameters. In this way, atmospheric variables at different scales were related to the spatial distribution of hailstorms.

The main purpose of this work is to study factors at different scales that are responsible for the onset of convection on hailstorm days, to improve knowledge about the formation of these phenomena and their prediction in southwest France. We first determined the regions most affected by hail, along with the most favorable time of year and most likely time of day for hail fall. Next, we selected the most intense hail events to study atmospheric variables most critical to hail formation, and related these to their spatio-temporal distributions.