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Hailfalls in southwest Europe: EOF analysis for identifying synoptic pattern and their trends

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ABSTRACT

One of the main challenges in studies of hail precipitation is the estimation of its trends in the context of global warming. The strong spatiotemporal variability of hailfalls, together with their small scale, makes it difficult to record all such events and build long and homogeneous databases. For this reason, obtaining direct observation trends yields large uncertainties. The study of atmospheric parameters at various scales that influence deep convection and its temporal change has been used to estimate possible trends in the frequency of hailfalls. In this article, we analyze atmospheric variability at synoptic scale during the warm season in Southwest Europe, using empirical orthogonal function analysis and hailfall records from dense hailpad networks in northeastern Spain and southern France. These networks have uninterrupted operation during the warm season and reliable data. This method allowed us to obtain spatial modes of variability and temporal changes, facilitating estimation of changes in hail frequencies. The results show that the main modes of variability of 500-hPa geopotential height facilitate the definition of patterns that favor hailfalls throughout the warm season, whereas lapse-rate patterns between 850 and 500 hPa are shown to be important in the central months of the hail season. In addition, temporal changes in patterns related to hailfall variability suggest changes in the hailfall distribution during the warm season, with a decrease in hail frequency during June and increase during July.

1. Introduction

In the current context of global warming, several studies have indicated that the frequency of hail and its associated losses have been increasing in recent years. Based on insurance claims, Kunz et al. (2009) found a significant increase in losses caused by hail in southwestern Germany. In northwestern Italy (Eccel et al., 2012) and mainland Croatia (Pocakal, 2011), significantly increased hailstorm intensity has been demonstrated using hailpad data. Using hail observations from weather stations and model reanalysis data, Burcea et al. (2016) found positive trends of hail frequency in Romania. Sanchez et al. (2017) and Hermida et al. (2015) revealed positive trends in hailfalls recorded by hailpads in the French Pyrenees.

One of the biggest problems in investigating the variability and trends of hailfalls is that they occur on a very small spatiotemporal scale (Punge and Kunz, 2016). It is therefore a challenge to obtain a complete record of hailfalls in a particular region. The representativeness of direct hail observations and hail data obtained from insurance claims is limited to small areas. Moreover, using these data, it is difficult to evaluate all hailfalls at supra-regional level. An alternative to direct observation is hail detection via remote sensors. The use of radars (Kunz and Kugel, 2015; López and Sánchez, 2009; Sánchez et al., 2013) and satellites (Merino et al., 2014b; Melcón et al., 2016) permits the detection of hail indirectly through the application of various algorithms. These tools yield greater spatial representation, but their indirect estimates make them unsuitable for the study of trends. Only certain regions with dense hail networks having direct and continuous measurements of hail have databases that permit monitoring of hailfall evolution. However, these types of databases are uncommon and have considerable spatial and temporal restrictions.

For this reason, one of the major efforts in recent years regarding hailfall analysis has been to examine relationships between hailfalls and synoptic, mesoscale and thermodynamic parameters. At synoptic scale, García-Ortega et al. (2011) analyzed geopotential height and temperature at the 850 and 500 hPa levels and humidity at the 850 hPa level, and their ability to characterize atmospheric conditions on days

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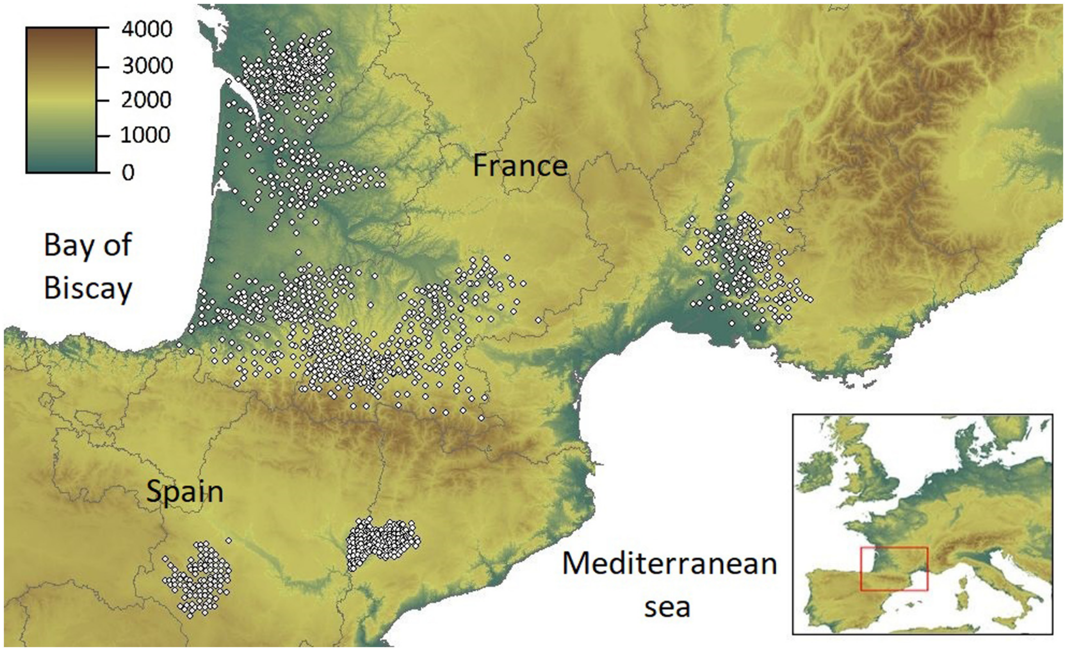

Fig. 1. Study area with location of hailpad networks used for HD selection.

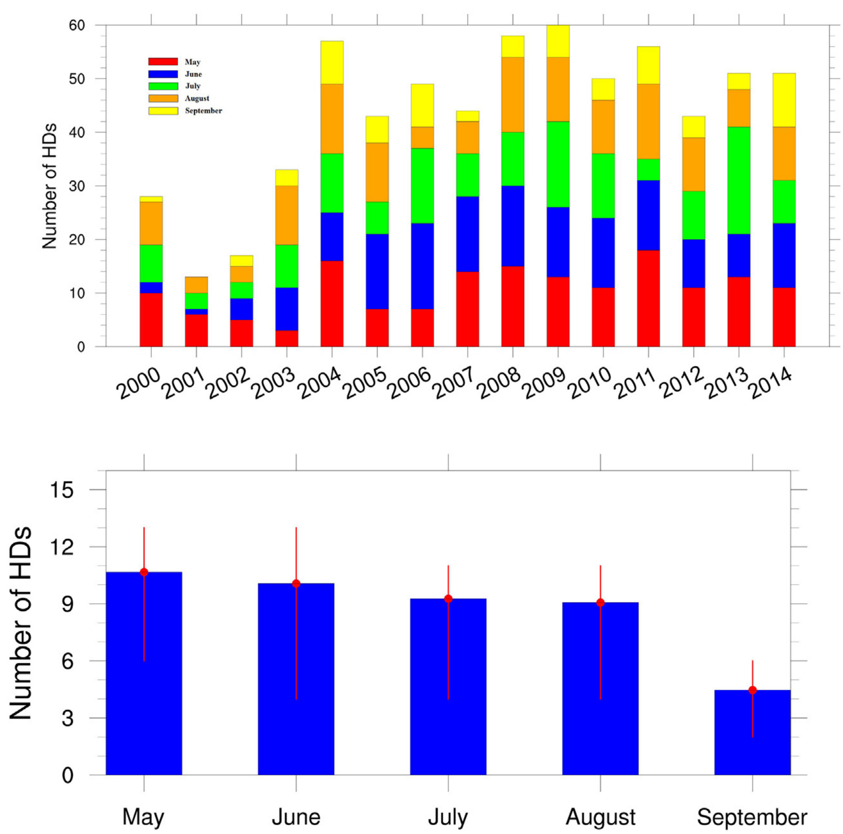

Fig. 2. Top: Yearly distribution of HDs by month (colors) between 2000 and 2014. Bottom: Monthly mean of HDs (bar chart) and interquartile range (red bar). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

with recorded hailfalls in the northwestern Iberian Peninsula. Similar fields have been analyzed to characterize hailstorms recorded in Central Europe (Suwała and Bednorz, 2013), France (Berthet et al., 2013), and Argentina (Mezher et al., 2012). Synoptic studies are fundamental to determining the variables related to hail development at a supra-regional level. For this reason, synoptic studies focus on investigating the characteristics of environments that favor hail, their evolution over long periods, and how these influence changes in trends of observed hail frequency.

In the western Mediterranean region, the hail season usually lasts from May through September. A key ingredient of severe convection is substantial energy needed to maintain strong vertical currents.