The anomalous thundery month of June 1925 in SW Spain: description and synoptic analysis

Francisco Javier Acero[1], Manuel Antón[1], Alejandro Jesús Pérez Aparicio[1,2], Nieves Bravo-Paredes[1], Víctor Manuel Sánchez Carrasco[1], María Cruz Gallego[1], José Agustín García[1], Marcelino Núñez[3], Irene Tovar[3], Javier Vaquero-Martínez[4], José Manuel Vaquero[1]

[1]Departamento de Física, Universidad de Extremadura, Badajoz, Spain
[2]Earth Remote Sensing Laboratory (EaRSLab) and Institute of Earth Sciences – ICT (Polo de Évora), Instituto de Investigação e Formação Avançada (IIFA), Universidade de Évora, Évora, Portugal
[3]Agencia Estatal de Meteorología (AEMET), Badajoz, Spain
[4]Departamento de Didáctica de las Ciencias Experimentales y de las Matemáticas, Universidad de Extremadura, Cáceres, Spain

Correspondence to: J.M. Vaquero (jvaquero@unex.es)

Abstract. In a routine search for meteorological events with a great impact on society in the Extremadura region (SW interior of Iberia) using newspapers, the month of June 1925 was detected as exceptional due to the large number of thunderstorms associated with significant loss of human lives and material resources. This extraordinary month underwent a detailed examination from various, complementary perspectives. Firstly, we reconstructed the history of the events, considering the most impacted locations and the resulting damages. Periodical publications, especially the widely circulated "Extremadura" newspaper in 1925, were pivotal in this regard. Secondly, we scrutinized monthly meteorological variables (precipitation, temperature, and cloudiness) using the lengthiest available data series in Iberia. This aimed to underscore the exceptional characteristics of June 1925. Lastly, we analyzed the synoptic situation of the thunderstorm events by employing 20CR reanalysis data. This approach allowed us to comprehend, from a synoptic perspective, the exceptional nature of this month. Thereby, a combination of a negative North Atlantic Oscillation (NAO) situation, elevated Convective Available Potential Energy (CAPE) values, large-scale lifting, and abundant total precipitable water vapor availability in the region was revealed.

1 Introduction

Thunderstorms are essential phenomena to understand the climate system (Markson, 2007; Rycroft et al., 2008). In addition to their scientific interest, thunderstorms have important consequences in our society since they produce a huge variety of dangers and problems such as heavy rain, lightning, large hail, tornadoes, etc. (Holle, 2016; Antonescu et al., 2017; Prein and Holland, 2018). The scattered nature of all these phenomena has made their study and prediction difficult until a few decades ago when large databases were available for the scientific community (see, for example, Dotzek et al., 2009, and Taszarek et al., 2021).

The most affected area by thunderstorms in the Iberian Peninsula is located in the northeast, especially in the mountainous regions of the Pyrenees (north Catalonia and Aragon) and the Iberian system (south Aragón). A climatology of stormy days and electrical discharges was recently published by Núñez Mora et al. (2019). In the scientific literature, several exceptional thunderstorm events in these areas of northeast Iberia can be found. For example, several authors have studied thunderstorms that have produced exceptional episodes of hail, such as the events that occurred in July 2001 (Tudurí et al., 2003), in September 2004 (Ceperuelo et al., 2006) or in June 2006 (Montanyà et al., 2009). In addition, other exceptional cases have been studied, such as the severe thunderstorm on October 4th, 2007, that affected the island of Mallorca (Ramis et al., 2009) or the convective system that affected Catalonia on March 21st, 2012, which produced a tornado (Bech et al., 2015). In all these cases, convective activity was very intense, although both the patterns in the general circulation of the atmosphere and the different local aspects can be very different. Climatological studies on thunderstorms in the rest of Iberia are scarcer. For example, Ezcurra et al. (2008) studied the rain characteristics of thunderstorms in northern Iberia during the five-year period 1992-1996. The establishment of lightning detection networks allowed scientists to carry out interesting studies for periods of around 10 years (Rivas Soriano et al., 2005; Santos et al., 2013). In addition, other studies have analyzed the impact of thunderstorms on social and economic aspects, such as wildfires (García Ortega et al., 2011).

In this context, we discovered a notable set of news about thunderstorms in the Spanish historical press during the month of June 1925. These journalistic reports strongly caught our attention since the geographical area where they occurred, the interior of southwest Iberia, is one of the regions of Iberia with fewer days of thunderstorms per year and the consequences described by journalists were exceptional. Therefore, the objectives of this article are (i) to make a detailed description of detrimental effects on lives, goods and infrastructures of that extremely stormy month of June 1925 in southwest Spain from news collected in newspapers, (ii) to carry out an evaluation of the observed meteorological data (precipitation, temperature, and cloudiness), even though these events occurred almost a century ago, and (iii) to analyze the synoptic situation that caused these exceptional thunderstorms.

2 Datasets and methodology

2.1 Historical sources

The historical press of the region of Extremadura (southwest of Iberia) has been consulted to obtain information about the meteorological events. In particular, we analyzed the newspaper "Extremadura", which led us to discover the unusual period of thunderstorms that occurred in 1925 affecting this region. The newspaper "Extremadura" was the most important newspaper in the region at that time, together with the newspaper "Hoy" which appeared later in 1933. Subsequently, the newspaper virtual library of the Spanish Government (www.prensahistorica.mcu.es) has also been consulted for the period between May 15th to July 15th 1925. The main Extremadura newspapers consulted in this library have been: "La Montaña" and "Correo de la Mañana". In addition, one national newspaper "La Correspondencia de España" has been analyzed. Eleven reports of thunderstorm events in Extremadura were found in the newspaper "Extremadura", nine in the newspaper "La Montaña", nine in the newspaper "Correo de la Mañana" and two in the newspaper "Correspondencia de España". Some characteristic examples of the news reports found can be seen in Figure 1 and some basic information about them are listed in Table 1. From all of them, a database has been created describing each event, its location, the date of the event and the publication of the news, as well as information on the impact of the event such as economics impacts, human losses, and injured people.

La tormenta de esta tarde

Ha sido de primera clase y de gran aparato "escénico"

La tormenta que esta tarde ha descargado sobre la capital, ha sido digna compañera de aquella otra de la noche del 7 de Junio.

Agua en abundancia, truenos ensordecedores, y gran número de chispas han sido los «elementos» integrantes de la tormenta.

Ignoramos los daños que hayan vuelto a experimentar las huertas que están de mal año.

Según nuestras noticias, en la ciudad no han ocurrido incidentes desagradables, habiéndose inundado solo contadas viviendas.

La calleja de la Machacona se convirtió en caudaloso río, gracias al atascamiento «endémico» de la atarjea de la Plaza.

Pero en fin.

«¿Por qué, por qué temblar?...» que dijo el zarzuelero. Hasta otra y no va más.

Furiosa tormenta

Un joven muere ahogado, sin que aparezca su cadáver

Comunican de Zarza de Granadilla que en aquel término descargó días pasados una furiosa tormenta, que causó grandes daños.

Del sitio llamado Teso del Hierro, desapareció el pastor de quince años Paulino González Sánchez.

Se supone que fué arrastrado por la impetuosa corriente que alcanzó el arroyo «Aldevara», al intentar vadearlo.

En unos matorrales pe la orilla del riachuelo, fué encontrado el morral que llevaba el joven.

Sus familiares, los somatenes, Guardia civil y vecindario, se dedicó a sondar el riachuelo hasta su desembocadura, en el Alagón, sin encontar el cadáver.

Continúan haciéndose gestiones para encontrarlo, aunque hasta ahora han resultado infructuosas.

La tormenta del miércoles

En la capital

La tormenta del miércoles, aunque fué breve, revistió caracteres de impetuosidad desconocida.

El centro de la nube estuvo sobre la ciudad, pués mientras en el Paseo Alto apenas si cayeron unas gotas, en la barriada de la estación llovió torrencialmente, anegándose algunas casas y almacenes.

Personas en peligro

Donde mayor gravedad revistió la tormenta, fué en el cercano pueblo de Malpartida de Cáceres.

Una chispa eléctrica rompió el tejado y un muro de una casa de la calle Pozo Marco.

La nube sorprendió en el campo a Gonzalo Gutiérrez, con su esposa Antonia Fajardo y un niño; a Julián Rebollo, Juan y Francisca Pavón, quienes se refugiaron en una encina.

Una chispa cayó en el árbol, matando a tres caballerías menores y produciendo diversas quemaduras calificadas de pronostico reservado a Gonzalo Gutiérrez, su esposa y su hijo y a Francisca Pavón.

No se ha tenido noticia de que la tormenta haya ocasionado otras desgracias.

HORROROSA TORMENTA

Grandes estragos

Comunican de Segura de León que al medio día de ayer, festividad de la Trinidad, se desencadenó una formidable tormenta de agua y granizo, acompañada de relámpagos y truenos que atemorizaron el vecindario.

Cayó una enorme cantidad de agua, inundándose las calles y varias casas.

Las carreteras y los caminos se hallaban anegados, haciendo imposible el tránsito.

Cuando pasó la tormenta y, por lo tanto, las horas de angustia del vecindario, llegó un pastor que presta sus servicios en una finca de don Vicente Gata comunicando que en la finca denominada «Casa nueva», propiedad de don Francisco Alba, a dos kilómetros del pueblo, habían caído varias chispas eléctricas, matando 51 ovejas.

En esta finca las sementeras fueron arrastradas por las aguas.

En otra finca más próxima al pueblo fué destruída una portada con palos y alambres, que fueron encontrados a un kilómetro de distancia.

Un molino de aceite, situado en el pueblo, propiedad de don José Antonio Maja Rebollo, sufrió grandes desperfectos, pues fué derribada una pared y desaparecieron varios trojes.

En el sitio conocido por las Ardilas los estragos causados por el temporal revisten mayores proporciones

De Zafra

Dos ahogados

La horrorosa tormenta que descargó días pasados sobre este término municipal ocasionó una enorme crecida de la ribera Peñaranda.

En el molino harinero denominado Adrián, se hallaban el dueño Eulalio Sánchez, de cincuenta años, y un convecino llamado Justo Berjano, de veintiocho. Ambos fueron sorprendidos por la fuerte avenida y arrastrados por las aguas sin que nadie pudiera evitarlo.

Durante la mañana siguiente al suceso la benemérita practicó trabajos para dar con los desaparecidos. Cuando el nivel de la ribera descendió fueron hallados los dos cadáveres.

El Juzgado de instrucción intervino, practicando las diligencias oportunas.

Figure 1: News clippings from the newspapers "Extremadura", "Correo de la Mañana" and "La Montaña" (courtesy of the Central Library of the University of Extremadura).

Table 1. Date, newspaper name, title [translated title], and a summary of the news that are reproduced in Figure 1 (from left to right).

Date and newspaper name	Tit~~t~~le	Summary
15/06/1925 La Montaña	La tormenta de esta tarde ha sido de primera clase y de gran aparato "escénico" [This afternoon's thunderstorm was first class and had great "scenic" effects]	There was heavy rain and deafening thunder in the Cáceres area. It was similar to the thunderstorm that occurred on June 7.
15/06/1925 La Montaña	Furiosa tormenta. Un joven muere ahogado, sin que aparezca su ~~cadaver~~cadáver [Raging thunderstorm. A young man drowns, but his body is still unavailable]	Raging thunderstorm in Zarza de Granadilla. A shepherd drowns while crossing the "Aldevara" stream. The body is not found, despite the efforts of law enforcement and family members.

11/06/1925 La Montaña	La tormenta del miércoles [Wednesday's thunderstorm]	A violent thunderstorm. The worst damage was in Malpartida de Cáceres, with three people injured by lightning.
09/06/1925 Correo de la mañana	Horrorosa tormenta [Horrible thunderstorm]	Formidable thunderstorm in Segura de León: streets and houses are flooded, roads and highways are impassable, and there is a great impact on agricultural activities.
11/06/1925 Correo de la mañana	De Zafra. Dos ahogados [From Zafra. Two drowned]	A huge thunderstorm caused the Peñaranda stream to rise. Two people drowned at Don Adrián's flour mill, where they were caught by a strong flood.

2.2 Meteorological data and reanalysis

The Spanish Meteorological Agency (Agencia Estatal de Meteorología, AEMET) provided the records for the time series construction of the three meteorological variables analyzed in this work: precipitation (P), temperature (T) and cloudiness (N). The relationship between the thunderstorm events and rainfall has been studied from 64 accumulated monthly precipitation series homogenized by AEMET (Luna et al., 2012). These rainfall time series cover 158 years from 1851 to 2008. Moreover, daily rainfall time series for seven locations placed over Extremadura region were used to analyze the short-term variability of precipitation in this region during June 1925.

With the goal to check the relationship between the thunderstorm events and temperature during June 1925, daily temperature records have been analyzed in this work using 20 long and reliable Spanish series~~ covering the period 1850–2003~~ (Brunet et al., 2006).

The cloudiness observed in June 1925 over Spain was analyzed in this work by means of the so-called parameter of cloudiness in 39 stations covering 146 years from 1865 to 2010. Thus, the parameter of cloudiness (PC) used in our work to characterize the cloudiness is defined (in percentage) as:

$$PC = 50 + 50 \cdot ((O - C)/N) \quad (1)$$

where O and C are the number of overcast and cloudless days, respectively, and N is the number of days in a given period (month, season, year). We have used the data provided by Sánchez Lorenzo et al. (2012) who inferred monthly series of the variable given by equation 1 from the number of cloudless and overcast days recorded every month in 39 Spanish stations ~~since 1866~~from 1865 to 2010. For that, those authors recovered monthly series of cloudless and overcast days ~~since 1865 ~~from different volumes of the publications entitled "Resumen de las observaciones meteorológicas efectuadas en la Península", edited by AEMET, from 1865 to ~~1950~~1960. Since 1961 cloud cover daily data were already provided in digital format by AEMET and, consequently, the parameter of cloudiness (equation 1) was derived from monthly frequencies of cloudless and overcast days in order to cover the 1961–2010 period. Capel Molina (1981) established that a day is defined as cloudless if the mean cloud cover from several daily observations is lower than 20%, while is defined as overcast if this mean is higher than 80%. Thus, if the cloud cover is recorded in oktas the thresholds could be less than 1.5 for cloudless days and greater than 6.5 for overcast days.

Figure 2 shows the distribution of P, T and N stations in the Iberia Peninsula (circumferences and circles). In addition, this plot also displays the location of seven P stations with daily data (inverted triangles) placed over the Extremadura region.

Additionally, the utilization of the latest version (version 3) of the NOAA/CIRES/DOE 20th Century Reanalysis (V3) data (provided by the NOAA PSL, Boulder, Colorado, USA, from their website at https://psl.noaa.gov) was implemented (Compo et al., 2011; Slivinski et al., 2019). This has been made possible by the latest data assimilation systems and several sets of historical meteorological observations. This particular dataset is well-suited for the intended analysis as it offers a continuous three- dimensional depiction of numerous meteorological variables dating back to 1836, encompassing a significantly longer period compared to the standard NCEP/NCAR (since 1948) or ECMWF (since 1958) Reanalysis datasets. In particular, 20CR uses an ensemble filter data assimilation method, thus providing . Therefore, a direct estimation of the most likely state of the global atmosphere (for each three-hour period). Moreover, there also is also an estimation of the uncertainties in that reanalysis. Evaluating the performance of the 20CR reanalysis in the historical part is not a simple task since it is impossible to make comparisons with other reanalyses and can only be done by comparison with independent observations (Slivinski et al., 2021). Some comparison exercises carried out have been satisfactory. In particular, in our study area, the 20CR results were satisfactory for the extreme precipitation event of autumn 1876 in the Guadiana River basin (Trigo et al., 2014). The upper level (250 hPa) information from the 20CR reanalysis will also be used in this work. It should be noted that it was derived primarily by statistical methods for the period examined and is not the result of a standard reanalysis. This means that it has a much higher level of uncertainty than the sea level pressure fields or the upper level information for periods where radiosonde information is available.

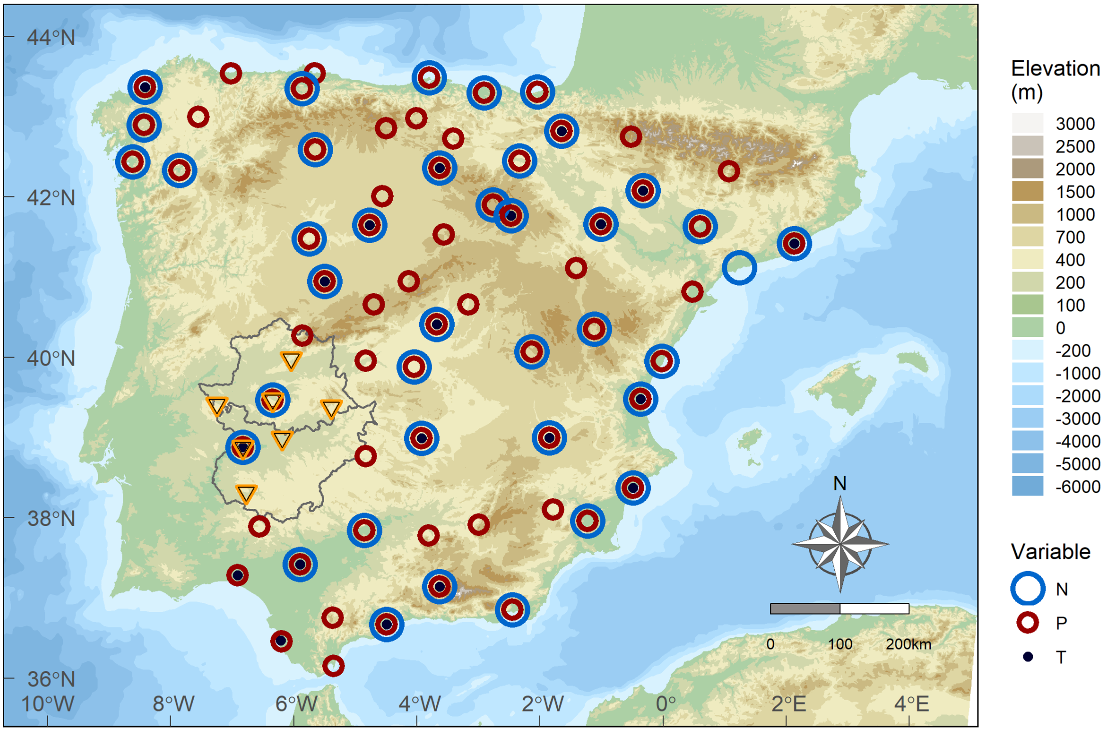

Figure 2: Map of Iberia with the borders of the region of Extremadura and its two provinces. The observatories are marked with blue circumferences (monthly cloudiness data, N), red circumferences (monthly precipitation data, P) or black dots (daily temperature data, T). Moreover, observatories with daily precipitation data in the region of Extremadura are shown with yellow inverted triangles.

3 Historical description of the stormy month of June 1925

This episode of thunderstorms that occurred in June 1925 had a great impact throughout Extremadura. Figure 3 shows the position and name of the multiple towns and villages located at the north, center and mainly south of Extremadura where different kinds of damages caused by the thunderstorms were reported. Extremadura exhibits a diverse orography, significantly influencing its hydrological patterns. The region has mountainous terrain, such as the Sierra de Gata and Sierra de San Pedro (in the north and west, respectively), with mountains above 1000 m height, which act as natural barriers to moist air masses from the Atlantic. Conversely, the plains in the south, like La Serena or La Campiña provide fertile ground for agriculture and livestock. Moreover, there are several important rivers in Extremadura. The main rivers are the Guadiana and the Tajo, which flow from east to west. Other smaller rivers are the Alagón, Tiétar, Zújar, Salor, Ardila and Guadiato. These rivers play a crucial role in the regions climate as they serve as conduits for moisture and influence local weather patterns. The region's orography influences the air mass movement, especially in the northern mountainous areas, where orographic lift leads to higher precipitation levels. Of course, the rivers contribute to the region's humidity levels, enhancing cloud formation and precipitation.

The regional Extremadura newspapers included wide information on the thunderstorms of June 1925 and their impact on the region. An overview of the thunderstorms and their impacts according to the newspaper reports is presented below.

The largest city where reports of thunderstorms have been found is Cáceres. This is the most important city in the province of Cáceres, one of the two provinces of the region of Extremadura. According to reports in the newspapers “La Montaña” and “Extremadura” there was a heavy thunderstorm in Cáceres on June 7^{th}, another one on June 10^{th}, a third one around June 14^{th}–15^{th} and a fourth one on June 19^{th}. In three of them (June 7^{th}, 10^{th}, and 14^{th}–15^{th}) there was flooding of streets and houses. Furthermore, the thunderstorm on June 7^{th} lasted for two hours, during which there were several lightning strikes, one of which caused a a widespread power blackout in the city. On the other hand, on June 10^{th} the thunderstorm lasted only ten minutes, but it was of great intensity with torrential rain and huge hailstones that severely damaged the countryside. The center of these two thunderstorms was the area of the city of Cáceres, with no rainfall in the surrounding area.

In other places, deaths were reported during some thunderstorms, such as it occurred in the Zafra, Villalba, Bienvenida and La Lapa zone on June 10^{th}, where a total of four people died, two of them drowned due to the enormous flooding of the Peñaranda riverbank and the other two were struck by lightning in the hut where they were sheltering from the thunderstorm, according to the newspapers “Extremadura” and “Correo de la Mañana”. Another death occurred in Zarza de Granadilla when a man was swept away by the current while trying to ford a stream on June 10^{th}, as reported in the newspaper “La Montaña”. The death of a child who drowned when she was swept away by a stream in the thunderstorm in Berlanga is also to be regretted, according to the news item of June 22^{nd} in the newspaper “Correspondencia de España”, where it is also stated that lightning killed three people in Llerena. The newspaper “Extremadura” reports that, in the village of Montemolín, there were fifteen consecutive days of thunderstorms, killing a man when he was struck by lightning. The same newspaper also reports that another person died from the same cause in the thunderstorm that occurred in Montánchez on June 8^{th}. However, the event with the highest number of deaths was the thunderstorm on June 18^{th} in Higuera de Vargas according to the newspaper “Correo de la Mañana”, in which five people died when they were struck by lightning while sheltering in a hut.

As well as the fatalities, there were several injured people and deceased animals. For example, in that same hut in Higuera de Vargas, apart from the death of those five people, four people were injured and eight pigs that were in the vicinity died. Moreover, according to the reports from the newspaper “La Montaña”, there were also two people injured in the thunderstorm of June 10^{th} in Cáceres. Two people suffered burns when they were struck by lightning in Malpartida de Cáceres and three donkeys were killed by the lightning according to the same newspaper. In addition, many animals drowned in different locations.

Another of the most frequent impacts of the thunderstorms were the floods that occurred in many places. According to the news reported in the newspaper “Correo de la Mañana”, in Segura de León a strong thunderstorm around June 7^{th}–8^{th} caused the flooding of a multitude of houses and streets. In addition, the strong flow of water caused the watercourses to break in several places, sweeping away animals, devastating the fields, and leaving the trunks of holm oaks bare due to the impact of the stones carried by the current. The same newspaper reports that further north, in Ribera del Fresno, there were also major floods due to a thunderstorm on June 16th. The most insignificant stream was transformed into a mighty river and the streets carried so much water that it was impossible to cross them. In some houses the water reached a height of one meter, collapsing walls and sweeping away everything in its path. A few days later, in the same area, the newspaper “Extremadura" reported a major thunderstorm on June 25th in the village of Hinojosa del Valle, during which the whole village was flooded, and several houses were destroyed. In addition, it is reported that a stream overflowed its banks in Jerez de los Caballeros due to another thunderstorm on June 21st. It must not be forgotten the overflowing of the Bodión river, the Peñara riverbank and the Guadiana river in the thunderstorm on June 10th in the Zafra area mentioned above.

It is worth mentioning the damage caused to infrastructures by the intense thunderstorms. There were collapsed bridges, such as the one over the river Víar during the thunderstorm on June 6th in the area of Montemolín according to the newspaper “Correo de la Mañana”. Another bridge fell over the Tagus River due to the thunderstorm on June 7th in the area of Santiago del Carbajo according to the newspaper “La Montaña”. In addition, it is reported that traffic between Santiago del Carbajo and a nearby village called Herrera de Alcántara was interrupted. The collapse of houses and walls was also very common in many towns during these thunderstorms, as occurred in Segura de León, Cáceres, Malpartida de Cáceres, Hinojosa del Valle, and Ribera del Fresno.

Crop and field damages were extensive in many of the locations where thunderstorms developed, leading to a major economic impact due to the region’s dependence on agriculture at that time. For example, a thunderstorm in Alconera on June 7th destroyed crops and trees, leaving only the subsoil in many places, according to the newspaper “Correo de la Mañana”. Something similar happened according to reports from the newspaper “Extremadura” on June 10th in Aldeanueva del Camino and on June 18th in Eljas, where the water and hail caused considerable damage to the orchards.

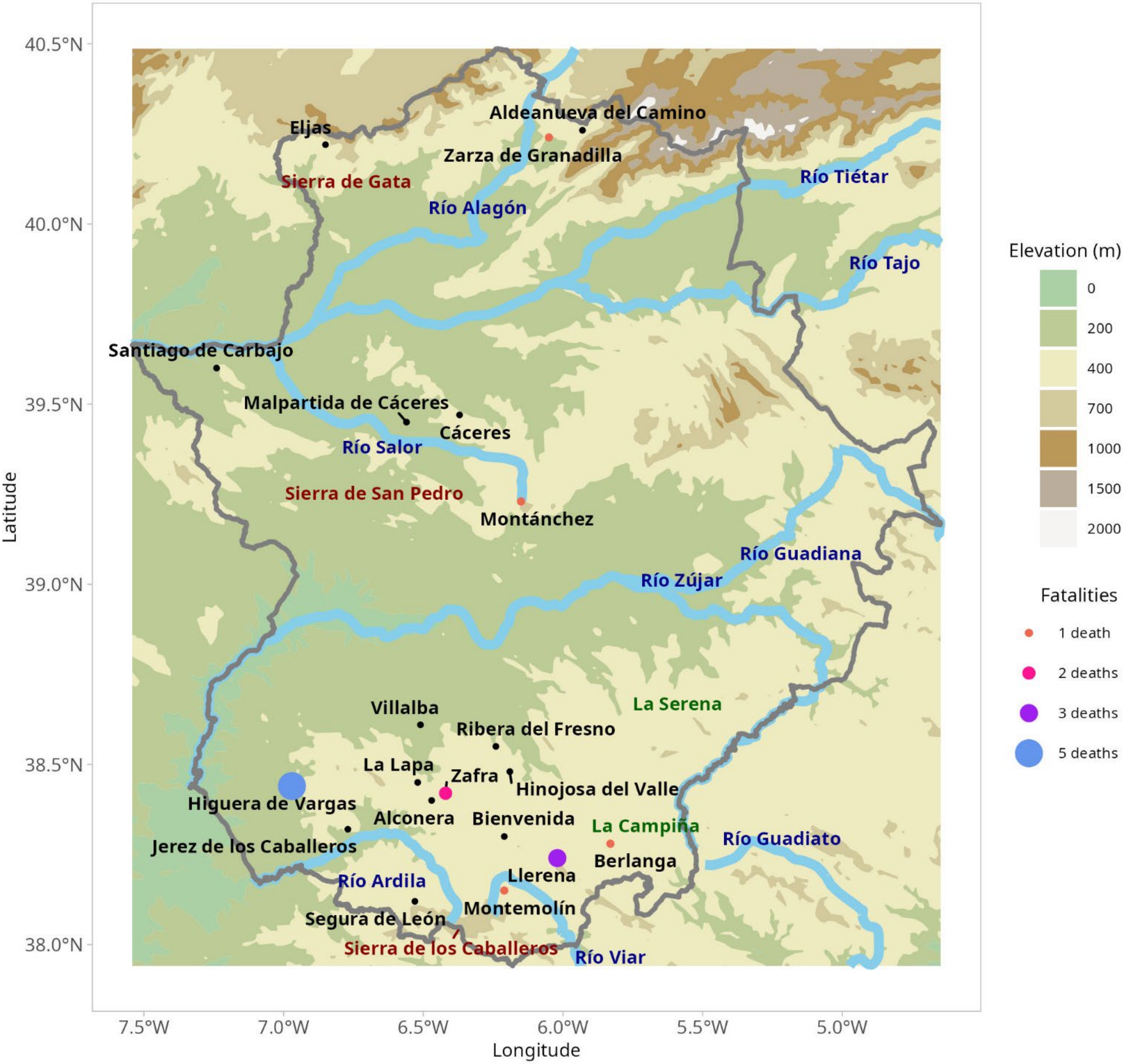

Figure 3: Geographical distribution of the Extremadura locations affected by the storms occurred in June 1925 according to the documentary sources consulted in this work. Color shows the number of deaths directly related to the thunderstorm events extracted from the documentary sources (black dots means no deaths reported).

4 Assessing the observed instrumental data

As this episode of thunderstorms in June 1925 led to hard impacts throughout Extremadura, it is necessary to analyze the behavior of rainfall in this month. For this purpose, daily rainfall data in seven locations over Extremadura were used. Figure 4 shows daily rainfall in June 1925 for these observatories. The local character of precipitation during thunderstorms is revealed. Most observatories recorded precipitation between June 2nd and 6th, Cornalvo (in the center of the study area) being the one with the highest values. During the rest of the month, thunderstorms and precipitation are more isolated, appearing in some observatories while there was no rain in others. Thunderstorms with rainfall higher than 20 mm day^{-1} were recorded on June 2nd-8th, 13th, 16th and 18th.

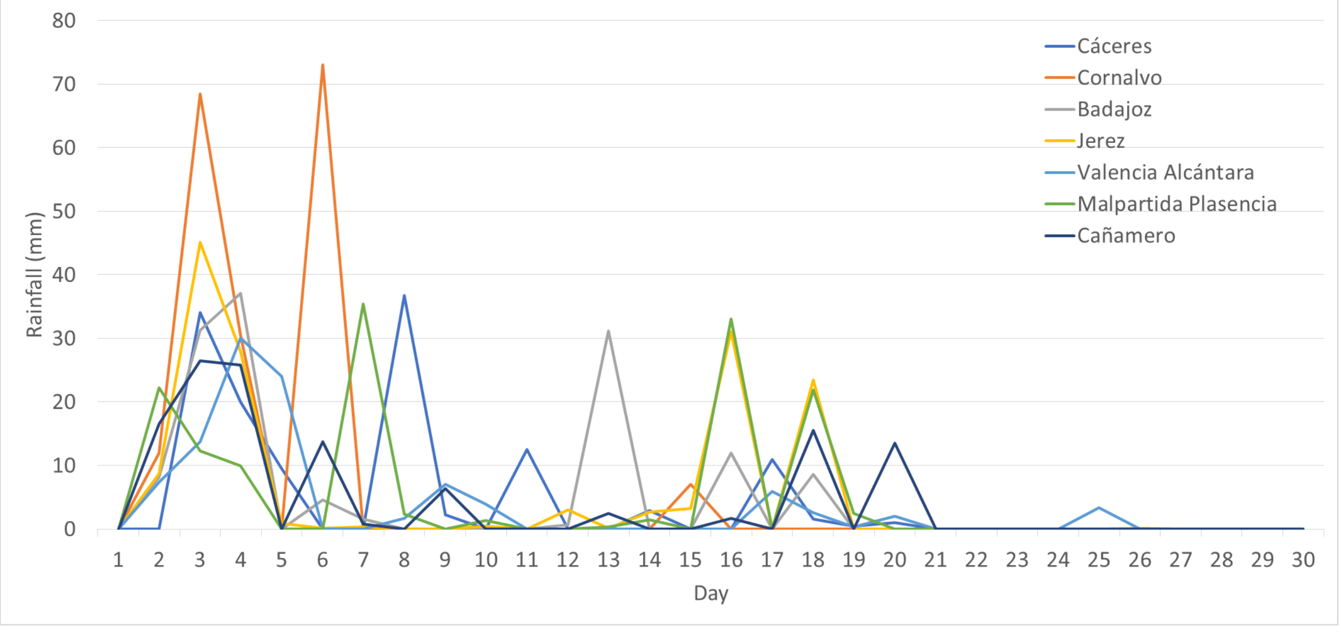

Figure 4: Daily rainfall recorded in seven observatories placed over Extremadura in the month of June 1925.

In order to analyze if the accumulated rainfall in the month of June of 1925 was remarkable, Figure 5 shows the ranking of that month compared to the remaining 157 June months for the time series of each observatory in peninsular Spain. The eight observatories marked in red represent the places where June 1925 was the first or the second wettest June and are placed in the southwest. In this same area, for most of the observatories, rainfall recorded in June 1925 is among the ten rainiest months of June for the whole time period. On the contrary, there are four observatories in the northwest showing that June 1925 was one of the driest months of June.

For the three meteorological variables analyzed in this work (precipitation, temperature, and cloudiness), the standardized anomalies between June 1925 and the average of June of the corresponding variable have been estimated as follows:

~~$Y = \frac{X_{June1925} - \bar{X}_{June}}{std(X_{June})}$~~, $Y = \frac{X_{June1925} - \bar{X}_{June}}{std(X_{June})}$

(2)

being ~~$X_{June1925}$~~ $X_{June1925}$ the value for the variable in June 1925, $\bar{X}_{June}$ ~~$\bar{X}_{June}$~~ and $std(X_{June})$ ~~$std(X_{June})$~~ the mean and the standard deviation of the variable for the month of June for the whole time series, respectively. In this section, variables such as rainfall, temperature, and cloudiness are analyzed.

Figure 6 (left panel) shows the rainfall anomalies for sixty-four times series located over peninsular Spain. Note that, in order to allow a better interpretation of the spatial behavior of the results, the anomalies were spatially interpolated by a kriging procedure. The highest anomalies are located over the southwest of Spain, with the study area showing anomalies over 3, i.e., in June 1925 it rained between 3 and 4 times more than normal in a month of June. For these observatories, June 1925 shows the highest accumulated rainfall of the 158 years. The rainfall anomalies decrease towards the north and northeast of Spain.

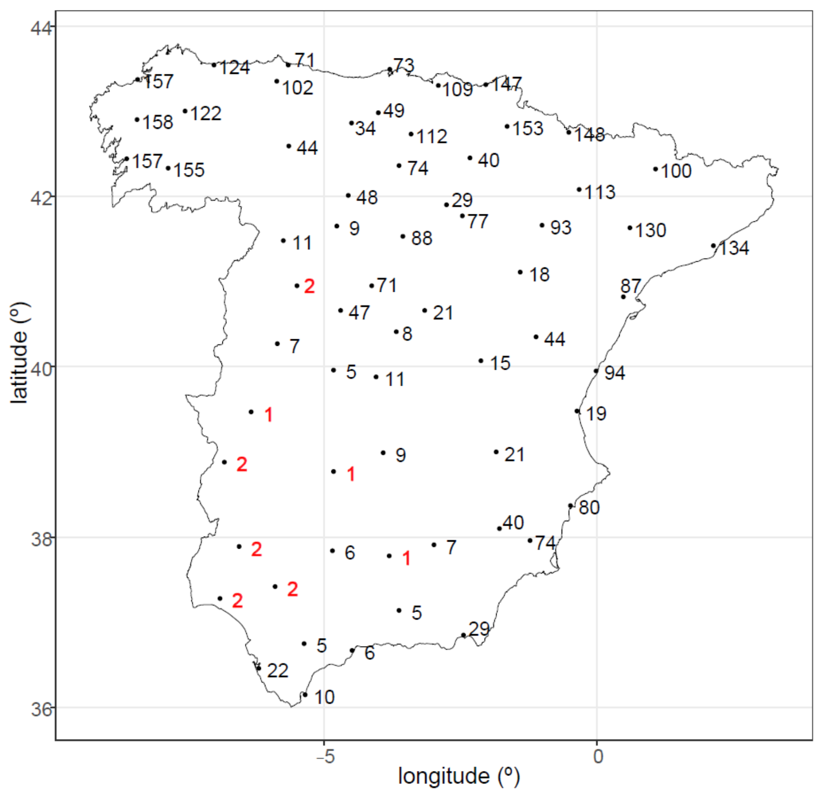

Figure 5: Spatial distribution of the rankings representing the accumulated rainfall in the month of June 1925 among the other June months in the 158 years (1851 to 2008) that make up the complete time series for each observatory. Red numbers represent the observatories where June 1925 is the first or the second wettest June.

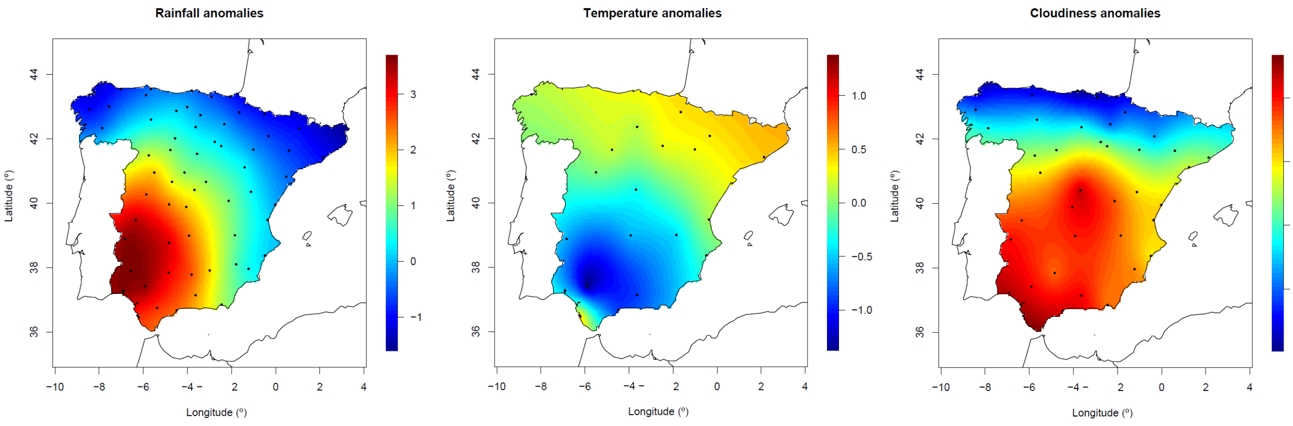

Figure 6: Rainfall (left), temperature (center) and cloudiness (right) anomalies for June 1925.

When studying the relationship between temperature and thunderstorm events, it can be expected that the temperature will be lower than usual in a month as rainy as the one that occurred in the study area. Figure 6 (central panel) shows the monthly temperature anomalies for our time series. Anomalies showing a colder-than-average June 1925 lie in the southwest although they are weak. Similarly as for the rainfall, the temperature anomalies decrease towards the northeast of Spain. Moreover, Figure 6 (right panel) shows the spatial variability of the cloudiness monthly anomalies for June 1925 with respect to the average for the 1866-2010 period in Spain. A clear dependence on latitude can be seen, with negative cloudiness anomalies for all northern locations and positive anomalies for the central and southern sites. In addition, it is appreciated that the central and southwestern regions of Spain present the highest cloudiness anomalies. Several locations exhibit extremely high cloudiness values in June 1925 compared to all months of June between 1866 and 2010. For example, June 1925 was an absolute cloudiness record in Madrid, Cuenca, and Granada. It marked the second maximum value in Badajoz, Toledo, and Málaga.

5 Synoptic analysis leading to the June 1925 events

In addition to the analysis of temperature, precipitation and cloudiness series, the synoptic situation of each day of June 1925 is analyzed in order to understand the reason for the stormy events during the month. For this purpose, the 20CR reanalysis data were used to carry out the analysis. The wind vector (streamlines) and the geopotential height at 250 hPa for each day of June 1925 are plotted in Figure 7. Jet streams are a core of strong westerly winds located in the upper levels of the troposphere. Therefore, the jet stream is easily identified in Figure 7. In summer, the polar jet stream is weaker than in winter, and this favors a wavier flow. The polar jet stream in the first days of June reached 50 m/s and the flow began to ripple (Figure 7). The wave broke on the third day of June bringing on a cut-off low located over the southwest of the Iberian Peninsula. During the next few days, the polar jet stream continued wavy, and an anticyclone began to form poleward of the cut-off low. This situation can be assimilated to a blocking system (Barriopedro et al., 2010; Lupo, 2021).

The cut-off low pressure system was one of the prominent patterns during June 1925 and the corresponding convection increased precipitation that was very intense locally. This could also explain the increase in cloudiness and lower temperatures than usual for the month of June in this region. Note that the persistent trough and cut-off low pattern shown at 250 hPa and also at 500 hPa is compatible with a strong low level southern flow (700 hPa or 850 hPa) over the area of study, especially about the province of Badajoz, where there is usually a flow from the south and southwest at low levels. However, orographic reinforcement of precipitation is not typical in the south of the province of Badajoz, since the mountains, even if they were aligned perpendicular to the flow, are not high enough. This effect is well known upwind of the southern flow, in the Sierra de los Caballeros (the peak of Tentudía 1104 m and the western summit of Los Bonales 1053 m), but the locations affected by the storms in 1925 (Figure 3) are all in the lee of the aforementioned flow. In fact, the entire province of Badajoz, except for the southern mountains, can be considered geographically as a large valley of the Guadiana River, open to the west-southwest. That is why this orographic forcing of precipitation does not occur here. Perhaps the specific orography in locations such as Jerez de los Caballeros, Higuera de Vargas, La Lapa, etc., could have had some influence not on the precipitation but on its channeling and could have generated some local effects such as flooding or overflows.

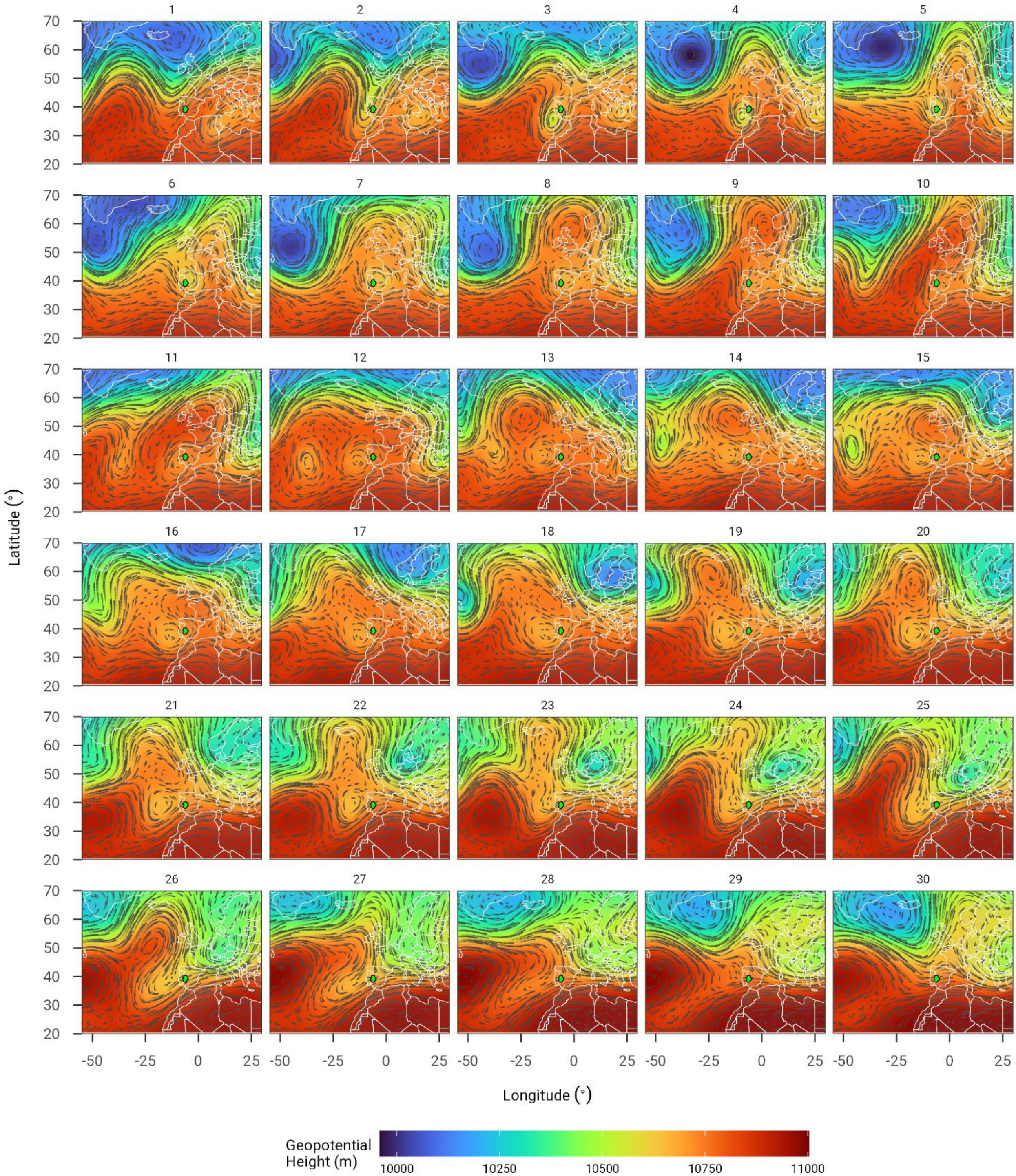

Figure 7: Wind vector (streamlines) and geopotential height at 250 hPa for each day of June 1925.

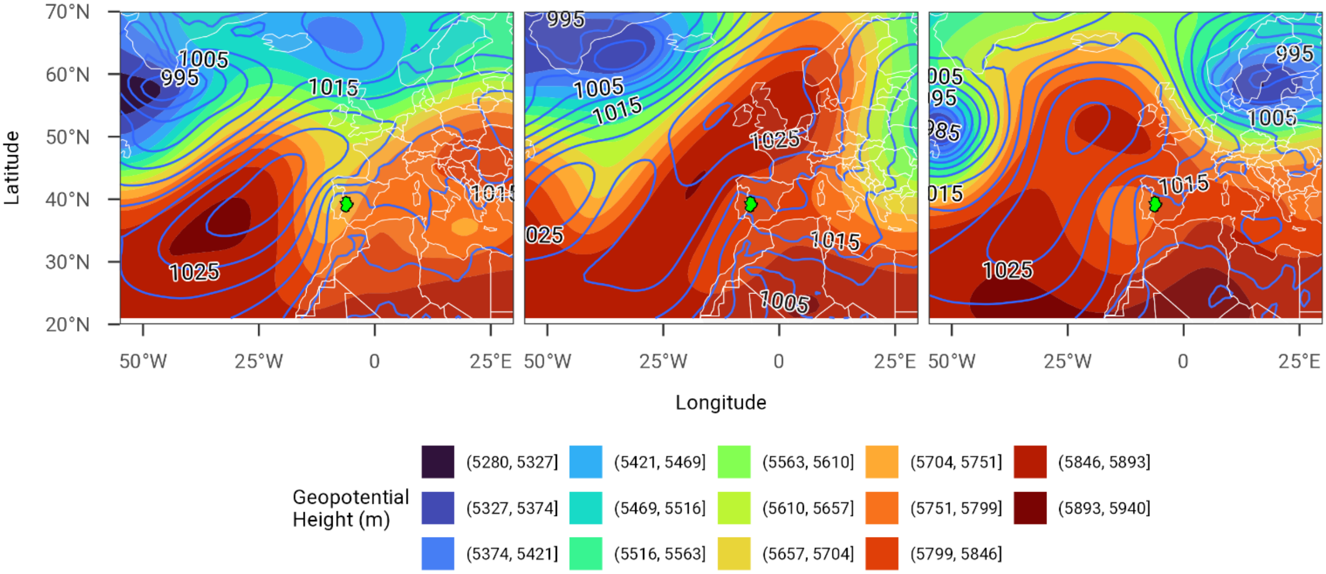

Figure 8: Synoptic situation of June 2nd (left), June 10th (center), and June 18th (right) showing an example of pattern types #5, #18, and #21, respectively, according to the classification by Santos et al. (2019). Geopotential height at 500 hPa is represented in top panels and SLP in bottom panels.

Synoptic pattern classifications are a useful analytical tool for understanding the weather of a region. We will use the synoptic pattern classification established by Font-Tullot (1983, 2000) to analyze the synoptic situation of each day of June 1925. Specifically, we will use the newfangled pattern classification carried out by Santos et al. (2019), which updates and improves the well-known Font-Tullot classification for the Iberian region. This synoptic classification consists of 23 different patterns. Santos et al. (2015) used the ERA40 reanalyses to review the objective classification of Ribalaygua-Batalla and Borén-Iglesias (1995). Moreover, the subjective classification of Font-Tullot (1983) was recovered in detail, proposing 23 synoptic patterns, illustrated with situations of 23 specific dates, from the 1970s-1980s.

The geopotential height at 500 hPa and the Sea Level Pressure (SLP) are analyzed for each day in order to identify which pattern corresponds to each day. Table 2 shows the seven patterns identified for June 1925. Five different patterns are identified between 1st and 22nd and all are associated with thunderstorms (except the pattern #16, not associated with thunderstorms, and #21, uncertain) by Santos et al. (2019). The most common patterns are #5 (Azores anticyclone and peninsular thermal depression), #18 (Ibero-African barometric trough), and #21 (barometric dam). Figure 8 shows an example of these three patterns showing the SLP (bottom panels) and the geopotential height at 500 hPa (top panels). Patterns #5, #18, and #21 are represented in Figure 8 left (June 2nd), center (June 10th), and right (June 18th), respectively. Pattern #5 is associated with storms between May and September, being more frequent in July and August. In addition, pattern #18 is common in June and is associated with fair weather, although it could be cut-off lows in southern Spain. Finally, pattern #21 is associated with fair weather with occasional storms, especially in northern Iberia. Between days 23 and 30 June 1925, the most common pattern was #10. This pattern is associated with cold and dry weather in southern Spain. As it can be seen in Section 3 and Figure 4, most of the stormy and rainy days occurred between days 1 and 22. In fact, as discussed in Section 4 in relation to Figure 4, thunderstorms with rainfall higher than 20 mm day^{-1} were recorded on June 2nd-8th, 13th, 16th and 18th. All these days, except for June 8th, are associated with patterns that could be compatible with thunderstorm or rain (see last column in Table 1). As evident from Section 3 and Figure 4, most stormy and rainy days occurred from day 1 to 22. Consequently, the synoptic analysis conducted in this section aligns with the observations documented in the newspapers.

Table 2: Patterns identified in June 1925 according to the classification by Santos et al. (2019).

Pattern	Brief description	Days	Storm or rain
#5	Azores anticyclone and peninsular thermal depression	1-3, 6, 7, 28, 29	Yes
#8	Atlantic anticyclone and peninsular thermal depression	4, 5	Yes
#10	Gulf of Genoa depression	24-27	No
#16	British-Scandinavian anticyclone	8, 9	No
#18	Ibero-African barometric trough	10-13	Yes
#20	Summer peninsular cold depression	23	Yes
#21	Barometric dam	14-22	Uncertain

~~Lastly, we have generated synoptic charts of the main meteorological fields, as well as different composites of the monthly mean values and anomalies regarding the climatological period covered by the 20CR reanalysis. A summary of our results is presented in Figure 9, which is made up of six panels. The top two panels show SLP while the middle two panels depict Convective Available Potential Energy (CAPE) and the bottom two panels display total precipitable water. The panels on the~~

right present the composite means of the variables indicated for June 1925 while the panels on the left exhibit the composite anomaly.

The top panels of Figure 9 show a typical negative North Atlantic Oscillation (NAO) situation with low pressures west of the British Isles and negative SLP anomalies in southwestern Iberia. The middle panels of Figure 9 reveal that western Iberia had high CAPE values in the context of the Atlantic and Mediterranean region, with positive mean anomalies in western Iberia during June 1925 (the values shown correspond to the composite mean of the entire month). Finally, the bottom panels present high values of precipitable water in the entire atmosphere in southwestern Iberia with the highest values of the anomaly over the region of Extremadura. Note that these monthly anomalies are calculated from the composite mean value (climatology time period selected for the calculus is 1981-2010). Therefore, the exceptional month of June 1925 in Extremadura was characterized by a combination of negative NAO situation, high CAPE values, and total water vapor available in this area. In any case, note that Figure 9 shows the largest CAPE in Spain for June 1925 was not located exactly in the south-western Spain but in north-western Spain and northern Portugal. It seems the 20CR reanalysis for such early times gives us significant patterns although perhaps the exact location of the details is a little displaced.

Lastly, we have generated synoptic charts of the main meteorological fields, as well as different composites of the monthly mean values and anomalies regarding the climatological period covered by the 20CR reanalysis. Following Doswell et al. (1996), thunderstorms and deep moist convection require three ingredients: moisture, instability and lift. Vertical wind shear is also required to allow storm organization (e.g. Markowski and Richardson, 2010). In the current manuscript, precipitable water content (moisture), CAPE (instability) and Omega (dp/dt, lifting) are analyzed.

A summary of our results is presented in Figure 9 and Figure 10. Figure 9 is made up of six panels. The top two panels show SLP while the middle two panels depict Convective Available Potential Energy (CAPE) and the bottom two panels display total precipitable water. The panels on the right present the composite means of the variables indicated for June 1925 while the panels on the left exhibit the composite anomaly.

The top panels of Figure 9 show a typical negative North Atlantic Oscillation (NAO) situation with low pressures west of the British Isles and negative SLP anomalies in southwestern Iberia. The middle panels of Figure 9 reveal that western Iberia had high CAPE values in the context of the Atlantic and Mediterranean region, with positive mean anomalies in western Iberia during June 1925 (the values shown correspond to the composite mean of the entire month). Finally, the bottom panels present high values of precipitable water in the entire atmosphere in southwestern Iberia with the highest values of the anomaly over the region of Extremadura. Note that these monthly anomalies are calculated from the composite mean value (climatology time period selected for the calculation is 1981-2010). Therefore, the exceptional month of June 1925 in Extremadura was characterized by a combination of negative NAO situation, high CAPE values, and precipitable water available in this area. In any case, note that Figure 9 shows the largest CAPE in Spain for June 1925 was not located exactly in the south-western Spain but in north-western Spain and northern Portugal. It seems the 20CR reanalysis for such early times gives us significant patterns although perhaps the exact location of the details is a little displaced.

Panels in Figure 9 are complemented by panels in Figure 10, that show Omega field at several pressure levels during June 1925 (left panels) as well as Omega field at the same pressure levels during all of June months for the period 1851-2014 except 1925 (right panels). Results on left panels show a negative anomaly in Omega at all pressure levels during June 1925 in western Iberia until a very high level far from surface (~150 hPa) where the lift seems to have disappeared. Moreover, while the sea level pressure anomaly is negative across much of Europe (Figure 9), western Iberia stands out as a region with stronger large-scale lifting than average when looking at the Omega field. This indicates that large-scale lifting could have been a relevant factor for the development of the thunderstorms in June 1925. Results on right panels show this negative anomaly is non-existent for June months for the full period of reanalysis 1851-2014 except 1925. It indicates the exceptionality of the month June 1925 treated on this work and not included in the ESWD (Dotzek et al., 2009) which only includes four severe weather phenomena for the year 1925 in eastern Spain.

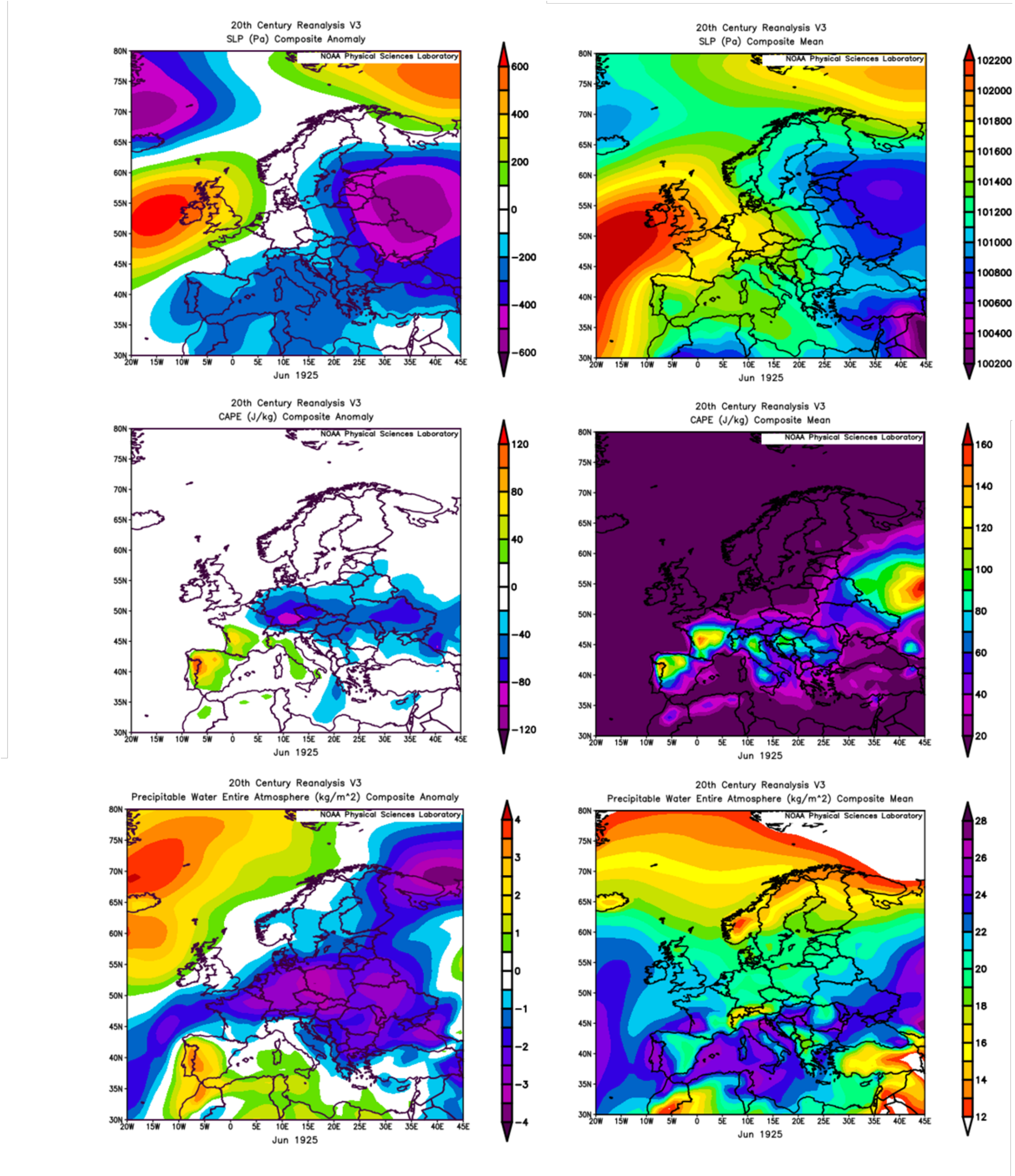

Figure 9: Composite mean (right panels) and composite anomaly (left panels) of SLP, CAPE and precipitable water entire atmosphere for June 1925 in the study area (top, middle, and bottom panels, respectively) from 20CR Reanalysis.

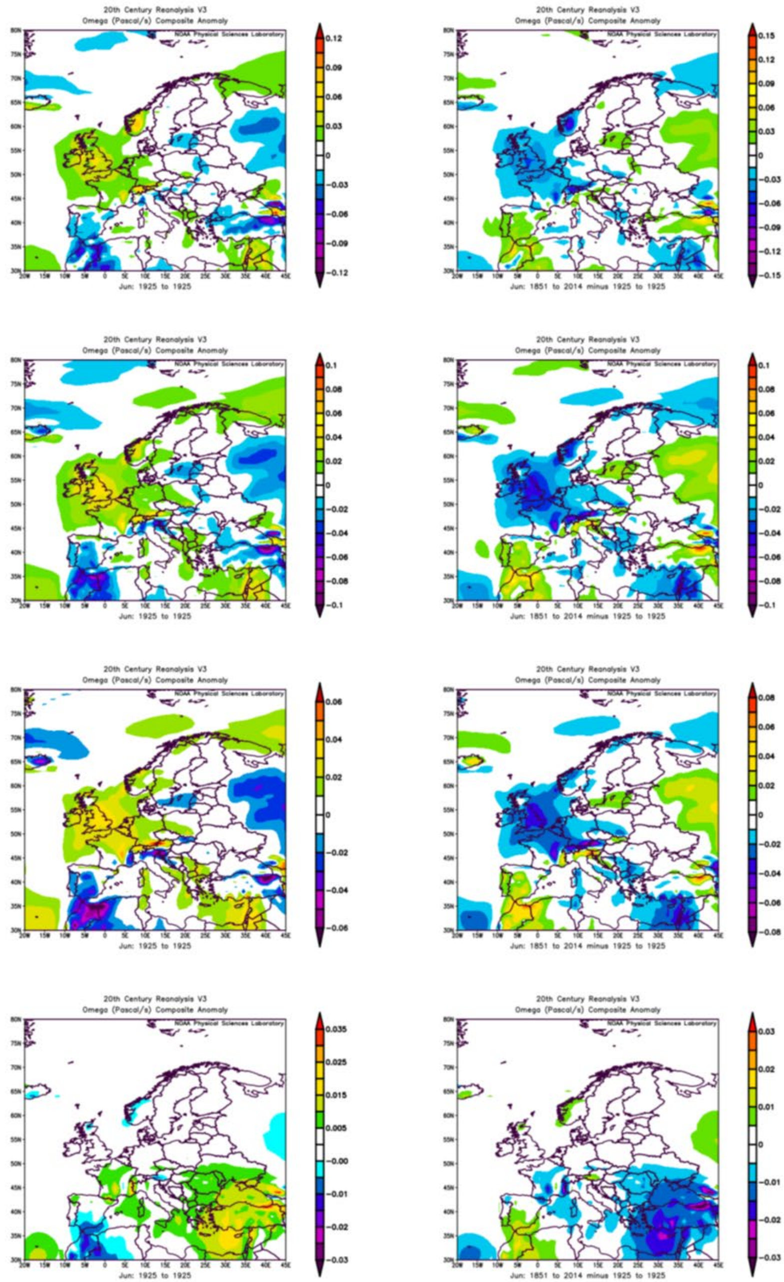

Figure 10: Composite anomaly for June 1925 (left panels) and composite anomaly for June months from 1851 to 2014 except 1925(right panels) of Omega (dp/dt) in the study area for pressure levels of 600, 500, 400 200 and 150 hPa(from top to bottom panels, respectively) from 20CR Reanalysis.

6 Conclusions

Thunderstorms are crucial for understanding the climate system and have significant societal implications due to their various hazards. The northeastern region of the Iberian Peninsula, particularly the mountainous areas of the Pyrenees and the Iberian system, is highly affected by thunderstorms. Studies have examined exceptional thunderstorm events in this region, including episodes of hail and severe thunderstorms. Climatological studies on storms in Iberia are limited but have explored rain characteristics and the impact on social and economic aspects such as wildfires. A notable set of news reports from June 1925 in the interior Southwest of Iberia drew our attention due to the region's infrequent storms and exceptional consequences described by journalists. In this study, we have provided a detailed description of the detrimental effects during that stormy month. Moreover, we have evaluated instrumental data from almost a century ago and have analyzed the synoptic situation that caused these exceptional thunderstorms.

The thunderstorms that occurred in June 1925 had a significant impact throughout Extremadura, Spain. Numerous towns and villages in the north, center, and south of Extremadura reported various damages caused by the thunderstorms. The city of Cáceres experienced multiple storms in June, with flooding of streets and houses on the 7th, 10th, and 14th–15th. The thunderstorms in Cáceres were characterized by heavy rain, lightning, and large hailstones that caused power outages and severe damage to the countryside. Other areas such as Zafra, Villalba, Bienvenida, La Lapa, Zarza de Granadilla, and Berlanga also reported deaths and injuries from lightning strikes, flooding, and stream currents. Animals were affected as well, with several cases of dead animals due to lightning strikes or drowning. Flooding and overflowing of rivers and streams were widespread, leading to damaged houses, streets, and fields. Bridges, houses and walls collapsed, and crops and orchards suffered extensive damage. The economic impact on agriculture was significant due to the destruction of crops and trees. These storms had a profound impact on the region, causing loss of lives, injuries, infrastructure damage, and economic losses.

During the thunderstorms in June 1925 in Extremadura, the behavior of rainfall in the region was analyzed. Daily rainfall data from seven locations in Extremadura were examined, revealing the local nature of precipitation during thunderstorms. The highest values of precipitation were recorded between June 2nd and 6th, with Cornalvo station experiencing the most significant rainfall. The rest of the month there were more isolated thunderstorms and varying precipitation patterns across the observatories. Several days, including June 7th, 8th, 13th, 16th, and 18th, had thunderstorms with rainfall exceeding 20 mm/day. To determine if the accumulated rainfall in June 1925 was exceptional compared to other June months, a ranking analysis was conducted. Eight observatories in the southwestern region of peninsular Spain marked in red in Figure 5 had either the wettest or second-wettest June on record in 1925. Most observatories in this area ranked among the top 10 rainiest Junes throughout the entire dataset. In contrast, four observatories in the northwest indicated that June 1925 was one of the driest Junes. We also examined standardized anomalies for precipitation, temperature, and cloudiness in June 1925 compared to the long-term averages (1850-2003). The rainfall anomalies were highest in the southwest, indicating that June 1925 had 3 to 4 times more rainfall than the average for a June month. The anomalies decreased towards the north and northeast of Spain. Temperature anomalies were lower than average in the rainy study area, with colder temperatures observed in the southwest. Cloudiness anomalies showed a clear dependence on latitude, with negative anomalies in northern locations and positive anomalies in central and southern regions. Central and southwestern Spain had the highest cloudiness anomalies, with several locations experiencing extremely high cloudiness compared to all other months of June from 1866 to 2010. Overall, June 1925 in Extremadura had significant rainfall, lower temperatures than usual, and increased cloudiness, particularly in the southwestern region.

We have analyzed the synoptic situation in June 1925 to understand the occurrence of stormy events during that month. The 20CR reanalysis data were used to examine the wind vector and geopotential height at 250 hPa for each day of June 1925. The presence of a polar jet stream and its waviness was observed, indicating a wavy flow pattern. The daily synoptic situations during this month show patterns associated with thunderstorms and rainfall in most of the days. Synoptic charts and composites of monthly meteorological fields for June 1925 were also generated. Our analysis suggests a negative NAO situation, with low pressure west of the British Isles and negative sea SLP anomalies in southwestern Iberia. Moreover, we have found high CAPE values in western Iberia, with positive mean anomalies during June 1925, and high values of precipitable water in southwestern Iberia, particularly in Extremadura. Overall, the exceptional month of June 1925 in southwest Iberia was characterized by a combination of a negative NAO situation, high CAPE values, large-scale lifting, and abundant available water in the region.

The analysis carried out in this article sheds light on the most extreme convective processes that can occur over southwest Iberia. The interest in these processes is enormous due to their catastrophic consequences.

Data availability

All raw data used in this study are public.

Author contributions

JMV planned the research; NB-P, IT, and JMV extracted the information from the newspapers; FJA, MA, NB-P, MCG, JAG, MN, and JMV made the formal analysis of the data; FJA, MA, MCG, JAG, MN, IT, and JMV wrote the manuscript draft; FJA, MA, AJPA, NB-P, VMSC, MCG, JAG, MN, IT, JV-M, and JMV reviewed and edited the manuscript.

Competing interest

The authors declare that they have no conflict of interest.

Acknowledgments

This research was supported by the Economy and Infrastructure Counseling of the Junta of Extremadura through project IB20080. A.J.P. Aparicio thanks Universidad de Extremadura and Ministerio de Universidades of the Spanish Government for the award of a postdoctoral fellowship Margarita Salas para la formación de jóvenes doctores (MS-11).

References

Antonescu, B., Schultz, D. M., Holzer, A., and Groenemeijer, P.: Tornadoes in Europe: an underestimated threat, Bull. Am. Meteorol. Soc., 98, 713–728, 2017.

Barriopedro, D., García-Herrera, R., and Trigo, R.M.: Application of blocking diagnosis methods to General Circulation Models. Part I: A novel detection scheme, Climate Dynamics, 35(7), 1373–1391, doi:10.1007/s00382-010-0767-5, 2010.

Bech, J., Arús, J., Castán, S., Pineda, N., Rigo, T., Montanyà, J., and van der Velde, O.: A study of the 21 March 2012 tornadic quasi linear convective system in Catalonia, Atmospheric Research, 158–159, 192-209, doi: 10.1016/j.atmosres.2014.08.009, 2015

Brunet, M., Saladie. O., Jones, P., Sigró, J., Aguilar, E., Moberg, A., Lister, D., Walther, A., López, D., and Almarza, C.: The development of a new dataset of Spanish daily adjusted temperature series (SDATS) (1850-2003), Int. J. Climatol., 26, 1777-1802, doi: 10.1002/joc.1338, 2006.

Capel Molina, J.J.: Los climas de España. Ed. Oikos-tau, 1981.

Ceperuelo, M., Llasat, M.C., López, L., García-Ortega, E., and Sánchez, J.L.: Study of 11 September 2004 hailstorm event using radar identification of 2-D systems and 3-D cells, Advances in Geosciences, 7, 215-222, doi: 10.5194/adgeo-7-215-2006, 2006.

Compo, G.P., Whitaker, J.S., Sardeshmukh, P.D., Matsui, N., Allan, R.J., Yin, X., et al.: The twentieth century reanalysis project, Q. J. R. Meteorol. Soc., 137, 1–28. doi:10.1002/qj.776, 2011.

Doswell, C. A., Brooks, H. E., and Maddox, R. A.: Flash Flood Forecasting: An Ingredients-Based Methodology, Weather Forecast., 11, 560–581, https://doi.org/10.1175/1520-0434(1996)011<0560:FFFAIB>2.0.CO;2, 1996.

Dotzek, N., Groenemeijer, P., Feuerstein, B., Holzer, A.M.: Overview of ESSL's severe convective storms research using the European Severe Weather Database ESWD, Atmospheric Research, 93, 575-586, doi: 10.1016/j.atmosres.2008.10.020, 2009.

Ezcurra, A., Saenz, J., Ibarra-Berastegi, G., and Areitio, J.: Rainfall yield characteristics of electrical storm observed in the Spanish Basque Country area during the period 1992–1996, Atmospheric Research, 89, 233-242, doi: 10.1016/j.atmosres.2008.02.011, 2008.

Font-Tullot, I.: Climatología de España y Portugal, Instituto Nacional de Meteorología, Madrid, 1983.

Font-Tullot, I.: Climatología de España y Portugal. Universidad de Salamanca, Salamanca, 2000.

García-Ortega, E., Trobajo, M.T., López, L., and Sánchez, J. L.: Synoptic patterns associated with wildfires caused by lightning in Castile and Leon, Spain, Nat. Hazards Earth Syst. Sci., 11, 851–863, doi:10.5194/nhess-11-851-2011, 2011.

Holle, R. L.: A summary of recent national-scale lightning fatality studies, Wea. Clim. Soc., 8, 35–42. 2016.

Luna, M.Y., Guijarro, J.A., and López, J.A.: A monthly precipitation database for Spain (1851-2008): Reconstruction, homogeneity and trends, Advances in Science and Research, 8, 14, doi:10.5194/asr-8-1-2012, 2012.

Lupo, A.R.: Atmospheric blocking events: a review, Annals of the New York Academy of Sciences, 1504(1), 5–24. https://doi.org/10.1111/nyas.14557, 2021.

Markowski, P. and Richardson, Y.: Mesoscale Meteorology in Midlatitudes, in: vol. 2 of Advancing weather and climate science, 1st Edn., Wiley, Somerset, ISBN 0470742135, 2010.

Markson, R.: The global circuit intensity: Its measurement and variation over the last 50 years, Bull. Amer. Meteor. Soc., 88, 1–19, 2007.

Montanyà, J., Soula, S., Pineda, N., van der Velde, O., Clapers, P., Solà, G., Bech, J., and Romero, D.: Study of the total lightning activity in a hailstorm, Atmospheric Research, 91, 430–437, 2009.

Núñez Mora, J.Á., Riesco Martín, J., Mora García, M.A.: Climatología de descargas eléctricas y de días de tormenta en España. Agencia Estatal de Meteorología, Madrid, 2019.

Prein, A.F. and Holland, G. J.: Global estimates of damaging hail hazard, Weather Clim. Extremes, 22, 10–23, 2018.

Ramis, C., Romero, R., and Homar, V.: The severe thunderstorm of 4 October 2007 in Mallorca: an observational study, Nat. Hazards Earth Syst. Sci., 9, 1237–1245, 2009.

Ribalaygua-Batalla, J., Borén-Iglesias, R.: Clasificación de patrones espaciales de precipitación diaria sobre la España peninsular y Baleárica. Informe Nº 3 del Servicio de Análisis e Investigación del Clima, Instituto Nacional de Meteorología, Madrid, 1995.

Rivas Soriano, L., de Pablo, F., and Tomas, C.: Ten-year study of cloud-to-ground lightning activity in the Iberian Peninsula, Journal of Atmospheric and Solar-Terrestrial Physics 67, 1632–1639, 2005.

Rycroft, M.J., Harrison, R.G., Nicoll, K.A., and Mareev, E.A.: An Overview of Earth's Global Electric Circuit and Atmospheric Conductivity. In: Leblanc, F., Aplin, K.L., Yair, Y., Harrison, R.G., Lebreton, J.P., and Blanc, M. (eds): Planetary Atmospheric Electricity. Space Sciences Series of ISSI, vol 30. Springer, New York, NY. doi: 10.1007/978-0-387-87664-1_6 (2008)

Sanchez-Lorenzo, A., Calbó, J., and Wild, M.: Increasing cloud cover in the 20th century: review and new findings in Spain. Clim. Past, 8, 1199–1212, doi:10.5194/cp-8-1199-2012, 2012.

Santos, C., Subías, A., and Roa, A.: Recuperación de la clasificación sinóptica de Font: reconstrucción con el reanálisis ERA40, AEMET, Madrid, 2019.

Santos, J.A., Reis, M. A., De Pablo, F., Rivas-Soriano, L., Leite, S.M.: Forcing factors of cloud-to-ground lightning over Iberia: regional-scale assessments, Nat. Hazards Earth Syst. Sci., 13, 1745–1758. doi:10.5194/nhess-13-1745-2013, 2013.

Slivinski, L.C., Compo, G.P., Whitaker, J.S., Sardeshmukh, P.D., Giese, B.S., McColl, C., Allan, R. et al.: Towards a more reliable historical reanalysis: Improvements for version 3 of the Twentieth Century Reanalysis system, Quarterly Journal of the Royal Meteorological Society, 145, 2876-2908, doi: 10.1002/qj.3598, 2019.

Slivinski, L.C. et al.: An Evaluation of the Performance of the Twentieth Century Reanalysis Version 3. Journal of Climate 34, 1417. https://doi.org/10.1175/JCLI-D-20-0505.1, 2021.

Taszarek, M., Allen, J.T., Marchio, M. et al.: Global climatology and trends in convective environments from ERA5 and rawinsonde data, npj Clim. Atmos. Sci., 4, 35, doi: 10.1038/s41612-021-00190-x, 2021.

Trigo, R.M. et al.: The record precipitation and flood event in Iberia in December 1876: description and synoptic analysis. Front. Earth Sci. 2, 3. doi: 10.3389/feart.2014.00003, 2014.

Tudurí, E., Romero, R., López, L., García, E., Sánchez, J.L., and Ramis, C.: The 14 July 2001 hailstorm in northeastern Spain: diagnosis of the meteorological situation, Atmospheric Research, 67–68, 541– 558. 2003.