SMC-Flood database: A high resolution press database on floods for the Spanish Mediterranean Coast (1960-2015)

Salvador Gil-Guirado[1,2], Alfredo Pérez-Morales[2], Francisco Lopez-Martinez[2]

[1]Interuniversity Institute of Geography, University of Alicante, P.O. Box 99, 03080 Alicante, Spain.
[2]Department of Geography, University of Murcia, Campus de la Merced, 30001 Murcia, Spain

Correspondence to: Salvador Gil-Guirado (salvagil.guirado@ua.es)

Abstract. High spatiotemporal flood databases are a necessary tool for proper spatial planning, especially in areas with high levels of exposure and danger to floods. This study presents the preliminary results of the Spanish Mediterranean Coastal Flood database covering the municipalities in this region. This database collects information on flood cases that occurred between 1960 and 2015 by systematically consulting the digital archives of the main newspapers in the study area. The search for flood information was conducted by means of using links between municipality names and 7 keywords that correspond to the most common ways of referring to a situation that is likely to describe a flood in Spain. This methodology has enabled reconstructing 3,008 flood cases at a municipal scale and with daily resolution while gathering information on the types of damage, intensity, severity and area affected. The spatiotemporal analysis of the data reveals hot spots where floods are especially intense and damaging when compared to highly-developed areas where the frequency of floods is very high. This situation is especially worrying insofar as we have detected a growing trend in the frequency and area affected by floods. However, one positive aspect is that the intensity and severity of floods follows a falling trend. The main novelty lies in the fact that the high-resolution spatial analysis has made it possible to detect a clear latitudinal gradient of growing intensity and severity in a north-south direction. This pattern subjects the coastal municipalities of the south of Spain to a complex floods adaptation scenario.

Keywords: SMC-Flood database, newspaper, Spanish Mediterranean coast, flood intensity, flood severity

1 Introduction

On the Spanish Mediterranean coast, the relationship between water resources and societies has been marked over time by the succession of periods of drought and catastrophic floods that have major socio-economic impacts. This dual system has left societies who need water resources for their agricultural and domestic demands exposed to an environment characterized by the torrential nature of rainfall (Gil-Guirado, 2013). In addition to the climatic conditions, it is also necessary to consider the social component. The economic growth experienced in the Spanish Mediterranean region over recent decades has increased exposure and vulnerability to the hazard (Pérez-Morales et al., 2018), with a significant rise in economic loss caused by floods (Barredo, et al., 2012). This socio-economic growth process has occurred without having properly planned any strategies to reduce the impact of flooding (Olcina-Cantos et al., 2010). One of the factors leading to a lack of strategic planning is the absence of a correct chronology of flood episodes (Hilker et al., 2009). As a result of this situation, land use plans are based on inadequate chronologies that do not report the real risk to the population in this area (Barriendos et al., 2014).

Several open and global flood databases have been developed over recent years (Brakenridge, 2010; WMO and UCL, 2014; Munich Re, 2017; ESSL, 2018; EM-DAT, 2018; European Environment Agency, 2018; NOOA, 2018; Swiss Re, 2018)[1]. Nevertheless, most of these databases have two limitations: i) the level of spatial resolution is variable between the municipal and regional scales; and ii) the number of events is considerably underestimated due to the use of indirect sources (Llasat et al., 2013a). Despite this, these databases have been used in a great deal of research to analyse the trends and changes observed in the behaviour of floods on different scales (Barredo, 2007; Ashley and Ashley, 2008; Kundzewicz et al., 2013; Jongman et al., 2015; Terti et al., 2017). Other studies, such as that of Adhikari et al. (2010), have compiled information from the main global-scale databases to increase the spatial resolution and improve the spatiotemporal representativeness of the data. Taking into account the bias of the original databases, the results of these studies may present biases related to underestimating the number of episodes and the failure to consider local variations.

On the other hand, several other studies like this have developed their own databases using primary sources (newspapers, books, historical documents, reports and technical documents) for different regions of the planet[2]. In this respect, the studies developed in the Mediterranean region are very remarkable. Some works have made notable efforts to synthesize flood data from different European regions in order to offer a homogeneous database for the western Mediterranean. In this regard, the works by Llasat et al. (2013a, 2013b) show the results of the FLOODHYMEX database analysis (produced in the framework of the HYMEX Project). Using newspaper sources with high spatial resolution, these works collect a large amount of data on flood events that occurred between 1981 and 2010. As for Spain, works of Llasat et al. (2009; 2013a, 2013b; 2016) and Barnolas and Llasat, (2007) show remarkable improvements in flood databases through the INUNGAMA flood database. Also in Spain, Barriendos et al. (2014) analysed a historical database obtained from historical documents, newspapers, official reports and expert studies, covering the period 1035–2013. For Portugal, Zêzere et al. (2014) present a database for the period 1865 to 2010, which they obtained from 16 national, regional and local newspapers. Other Mediterranean countries present equally valid initiatives, such as Diakakis et al. (2012) for Greece, whose work covers the period 1880 to 2010 using journalistic sources and flood event databases from state civil protection agencies. Another important example in Greece is the NOA Database (Papagiannaki, et al., 2013), which is also based on press articles that are constantly updated with information on weather and impact intensity classification. Italy also has adopted a large amount of initiatives to ascertain at a high level of spatiotemporal resolution the flood risk to its populations. In this respect, projects have been developed for specific regions of Italy. Specifically, for the region of Calabria, Polemio and Petrucci (2012) and Petrucci et al. (2018) analyse the variability of floods at the municipal level between 1880 and 2007, doing so by using newspaper and

[1] For more detailed information, the studies of Adhikari, et al. (2010), Bouwer (2011), Llasat et al. (2013a) and Napolitanao et al. (2018) include a detailed catalogue of some of these databases and their scope.

[2] For example: FitzGerald et al. (2010) for Australia; McEwen (2006) for Scotland; Glaser and Stangl (2004) for Central Europe; Quan (2014) for Shanghai; and Brázdil et al. (2014) for Southern Moravia (Czech Republic).

historical documents for their reconstruction. For the region of Campania, Vennari et al. (2016) reconstruct more than 500 flood events for the 1540 to 2015 period using historical documents. However, the project at the largest scale, the AVI Project, was based on the studies of Guzzetti et al. (2005) and Salvati et al. (2013), whose results made it possible to establish a high-resolution floods and landslides database for the whole of Italy between AD 68 and 2010. Basically, the AVI Project uses primary documentation, but with detailed information on deaths and displaced people.

The aim of most of these works is related to analysing flood trends for the period of time reconstructed. However, the relationship between increases in exposure, losses and impacts of floods does not follow a growing linear function. In fact, climate variability, defence infrastructures, adaptation measures and the increase in exposure have changed both social perception and flood trends (Jongman et al., 2014). In this respect, it is necessary to stress the existence of a negative correlation between the duration and direction of the trends. Whilst negative trends appear in studies using data that covers several centuries, positive trends appear in studies that analyse data on the last half-century. These divergences are due both to capturing climatic oscillations in data with a long duration (Barriendos et al., 2014) and to the heterogeneity of the sources used during recent years (Brázdil et al., 2014). Furthermore, the increase in exposure to flood risk has led to a rise in flood trends (Perez-Morales et al., 2018).

Among the different sources used for flood databases, newspaper sources allow homogenizing the documentary volume of different countries over at least the last 150 years. In fact, most of the studies that reconstruct floods for more recent periods have used newspapers as their main source of data (e.g., FitzGerald et al., 2010; Zêzere et al., 2014). Despite the fact that journalistic sources describe the impacts of floods on societies in great detail, they are of a high spatiotemporal resolution and have a large quantity of information to deal with, thus making it necessary to reduce both the area of study and the period analysed. Although the compilation of information is obviously an arduous task involving detailed archive work, it's the results accurately reflect the impact of floods (Barriendos et al., 2014).

To reduce the knowledge deficit regarding the spatiotemporal variability of floods and to more efficiently zone the Mediterranean coast according to flood risk, we have developed a high-resolution flood database by means of a methodology based on exploring the digital archives of the main newspapers published in the area. This database, the Spanish Mediterranean Coastal database (or, SMC-Flood database), includes all the flood cases recorded in newspapers for the different municipalities of the Spanish Mediterranean coast from 1960 until 2015. Here, we should clarify the difference between flood cases and flood events. We consider a flood case to be when a municipality has suffered some economic or social impact due to rain on a specific day. However, a flood event refers to an atmospheric situation on a specific day or in a time period that may have affected several municipalities at the same time (several flood cases). In this way, a flood case always corresponds to an affected municipality on a particular day, while an event may involve several municipalities and days. For example, during the flood event of October 1973, there were 27 flood cases along the coast in the provinces of Almeria and Murcia on the 18th and 19th of that month. Considering cases and not events implies a large number of records in comparison to databases that consider only flood events.

Therefore, the main objective of this paper is to present the preliminary results of the SMC-Flood database, thus providing an indicator of the potential of using this type of high resolution database for research. Our objective is especially relevant to areas like the Spanish Mediterranean coast, where population growth in recent decades has led to an unbridled increase in exposure to flood risk. In this regard, this paper has secondary objectives of analysing the temporal spatial variability of flood cases in the study area and detecting hot spots with high flood risk.

In future research, this database will be used for various purposes, such as for evaluating flood prediction tools and validating risk thresholds according to exposure and vulnerability conditions. In general, the SMC-Flood database will contribute to improving the understanding of the flood processes in an area of special economic, climatic and social interest.

2 The Spanish Mediterranean coast: "A flood risk-region"

The study area includes all the coastal municipalities of the Spanish Mediterranean Sea on the Iberian Peninsula. In total, there are 179 municipalities integrated into 11 provinces and 4 autonomous communities (see Fig. 1). The total area is 13,381 km^2 (2.64% of Spain's total area), with a population of 8,413,290 inhabitants in the year 2016 (18% of the Spanish population) (INE, 2018) and an average population density of 1,200 inhab/km^2, a figure far higher than the average for the EU (119) and for Spain (92).

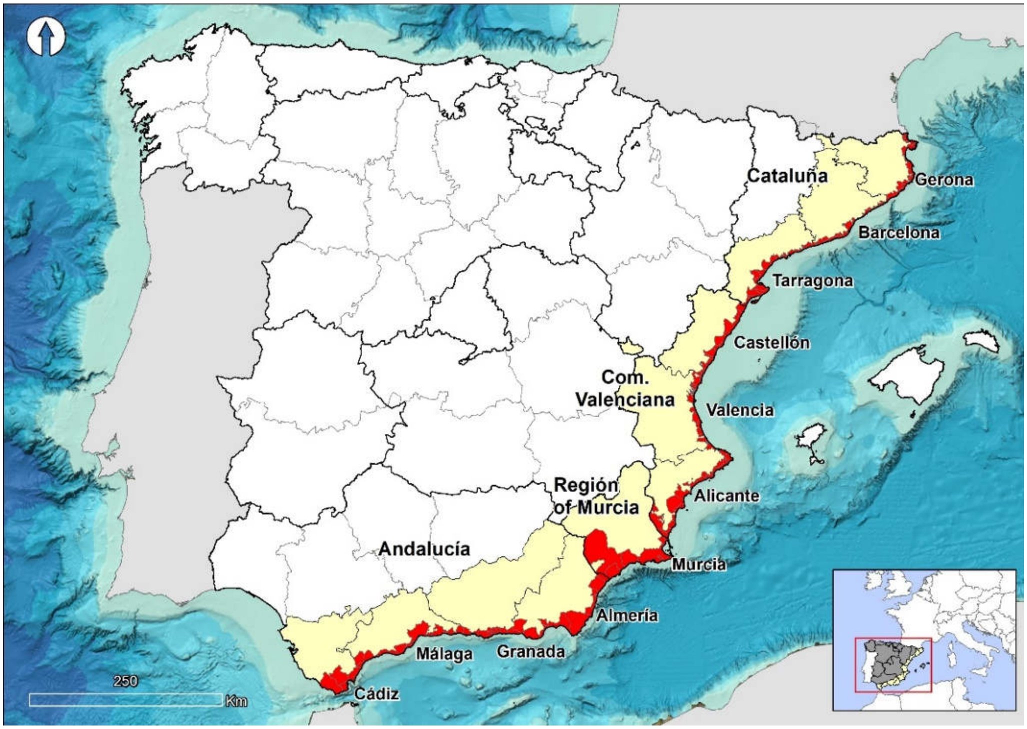


Figure 1: Coastal municipalities of the Spanish Mediterranean Sea along the Iberian Peninsula.

Due to the climatic and hydrological conditions of the Spanish Mediterranean basins, as well as the intensive anthropic transformation that has taken place, this space has become a “risk region” with a high level of vulnerability (Olcina-Cantos et al., 2010). The rainfall climatology in the western Mediterranean is marked by high variability coefficients (above 35%). Thus, 25% of rain days concentrate more than 75% of precipitation (Martín-Vide, 2004). The seasonality of torrential rains over the Spanish Mediterranean region is marked by a maximum at the end of summer and especially during the autumn (Llasat et al., 2013a). This maximum is due to warm, humid air coming in at low levels from the sea (Gilabert and Llasat, 2018: 1864). These atmospheric situations can be accentuated by the presence of a closed upper-level low (Sumner et al., 2003), which has become completely displaced (cut off) from the westerly current and moves independently of that current (Pagán et al., 2016). However, convective precipitations are the trigger for a large number of torrential rain episodes that are of low spatial extent and especially related to flash floods (Gilabert and Llasat, 2018). What is more, this climate scenario can become more dramatic in the future. Sumner et al. (2003) highlighted a notable increase in most synoptic situations with an easterly flow on the Spanish Mediterranean coast. These situations are prone to generating torrential rains and thus increasing flood hazards.

Added to this climatic scenario is the effect of an abrupt relief, with sharp gradients (Gilabert and Llasat, 2018) and scarce vegetation, which increases the quantity of effective rainfall becoming run-off. Furthermore, the presence of pre-littoral reliefs exacerbates these precipitations and explains part of the great spatial variability of the precipitation during a single atmospheric event (Romero et al, 2000).

In addition, this climatic scenario is complicated by the social component. Because of the intensive agriculture, industry in the major urban centres, trade and tourism, this region is the main centre of urban growth (Burriel, 2015). Thus, the resulting dynamic economy places it among the highest rates of population and economic growth in Europe over the last 50 years.

3 Methodology and sources

The SMC-Flood database contains information about flood cases at the municipal level that were published in printed newspapers and took place among the Spanish Mediterranean coastal municipalities (henceforth SMCM) between AD 1960 and 2015. The newspapers used were selected according to the following criteria: i) the highest circulation in each one of the four autonomous communities studied; and ii) its head office is located in the same autonomous community (see Table 1). This criterion ensures the reliability of the data, since news coverage of floods is more extensive when the original source of the data is a newspaper whose office is in the same autonomous community.

Table 1: Newspaper sources for the SMC-Flood database:

Newspaper	Type of Access	Newspaper Library Link	Period	Main coverage region	Head office
ABC	Open	http://hemeroteca.abc.es/avanzada.stm	1903-Now	Andalusia	Seville
LV	Open	https://www.lavanguardia.com/hemeroteca	1881-Now	Catalonia	Barcelona
EMV	Restricted	-	1872-Now	Valencian Community	Valencia
LVM	Restricted for news before 2006	-	1903-Now	Region of Murcia	Murcia

*The head office of the newspaper ABC is in the city of Seville (Andalusia); that of the newspaper La Vanguardia (LV) is in the city of Barcelona (Catalonia); that of the newspaper El Mercantil Valenciano (EMV) is in the city of Valencia (Valencian Community); and that of the newspaper La Verdad de Murcia (LVM) is in the city of Murcia (Region of Murcia.

The information from these newspaper archives is available digitally through both open access (LV and ABC) and restricted access (EMV and LVM). When access was restricted, we obtained an unrestricted password for the EMV free of charge within the framework of scientific cooperation. In the case of LVM, we carried out the search on the central computer of the newspaper's head office in the city of Murcia.

The digitized documents facilitated keyword searching for the information in the archive search engines of each newspaper. The first step consisted of relating each municipality (179) to its corresponding autonomous community's newspaper. However, in some cases, searching for information in some other newspaper completed the level of detail on specific cases and municipalities. Additionally, we consulted the specific bibliography to rule out any data gaps, for which the main source of information was the Catálogo Nacional de Inundaciones Históricas (Pascual and Bustamante, 2011). It is necessary to validate the results, especially when taking into account certain problems related to using newspaper sources, such as: inhomogeneity, duplicity of information and contradictory information (widely discussed by Llasat et al., 2009 and 2013a). Furthermore, these newspaper-source problems become more evident going back in time (more than 50 years), since journalistic sources are relatively more consistent over recent decades. In light of the issues above, the authors conducted the query procedure manually in order to eliminate some of the indicated problems from this database. Secondly, we carried out the systematic search for news where the name of each municipality appears together with any of the 7 keywords/phrases selected (see Fig. 2, Panel a). These keywords correspond to the most common ways of referring to a situation that is likely to describe a flood in Spain:

1. "Inundación" (Flood).
2. "Inundaciones" (Floods).
3. "Riada" (Flash flood).
4. "Lluvias torrenciales (Torrential rains).
5. "Fuertes lluvias" (Heavy rains).
6. "Intensas lluvias" (Strong rains).
7. "Tromba de agua" (Severe downpour).

In addition, the search was duplicated for those municipalities in Catalonia and the Valencian Community that have language variations (e.g., Alicante/Alacant, La Escala/L'Escala, El Puerto de la Selva/El Port de la Selva, Sagunto/Sagunt). In this way, we ensured that the same search criteria were fulfilled within all cases.

This initial search produced more than 1,500,000 possible results (news pages). Obviously, several keywords may be present on one page of news. In many other cases, the name of a municipality may appear on the page of a news item on floods, but without having been affected by that flood. In relation to this last point, it is possible to limit searches to cases in which the keywords are connected directly to the name of the town (i.e., "Torrential rains in Barcelona"). However, we found that this excessively restricted our search results, thus leading to many missing news items that had actually reported on specific floods. The reason for this is that keywords frequently appear in the headlines while the body of the news report describes the impacts and identifies the affected municipalities.

To filter the initial search results, each news item was saved in a digital file with the date of the news, followed by the initials of the newspaper (LVG, ABC, LVM or EMV) and, finally, the page number of the newspaper where it was reported. On many occasions, news about a flood in a specific town appears on different pages within the same day, offering varied and complementary information. Fortunately, this system for the coding news enabled elimination of duplicate keywords as well as municipalities (the same piece of news describes floods in various municipalities). Thus, the file on possible floods was reduced to 23,580 pieces of news for the SMCM.

The next step involved transforming qualitative information into quantitative information (see Fig. 2, Panel a). To this end, we consulted all the news filed and proceeded to code the news text onto spreadsheets. Digitizing the news pages by means of Optical Character Recognition (OCR) substantially facilitated this arduous task. Furthermore, the coding complied with the following classification protocol (see Fig. 2, Panel b): every flood was assigned its exact date of occurrence (the date of the flood is at least one day before the date of the news). Next, the affected municipality or municipalities were defined. Finally, the intensity of each flood was determined according to 3 levels (Camuffo and Enzi, 1996; Barriendos et al., 2003; Llasat, et al., 2005; Barriendos et al., 2014):

- Level 1 (L1): **ORDINARY** flood. A flood without overflow and minor damage.
- Level 2 (L2): **EXTRAORDINARY** flood. A flood with overflow and major damage.
- Level 3 (L3): **CATASTROPHIC** flood. A flood with overflow, general destruction and deaths.

Level 1 floods refer not only to cases of ordinary flooding in river flow, but also to flash floods and in situ floods outside the river’s floodplain. For this reason, Level 1 floods are valid for reporting variability in climate (changes in rain patterns) and social factors (changes in exposure or vulnerability) (Llasat et al., 2016), though they are not valid for reporting the hydrological variability of rivers. Accordingly, some works that analyse the hydrological variability of the rivers exclude L1 floods from their analyses (Llasat et al., 2005). For this reason, we obtained 10 dichotomous variables for indicating the presence (1) or absence (0) of any effects/damages produced by a flood in each municipality. Thus, we categorized the information on the type of damage suffered in a simple manner, always aware of the difficulty inherent in consistently objectivizing quantitative information in time and space (Gil-Guirado et al., 2016). These variables that we created give us a rough idea of the scope of damage caused by each flood. Specifically, the damage variables are the following: agriculture; cattle; fishing; roads; industry; trade; buildings; tourism; fatalities; and injured.

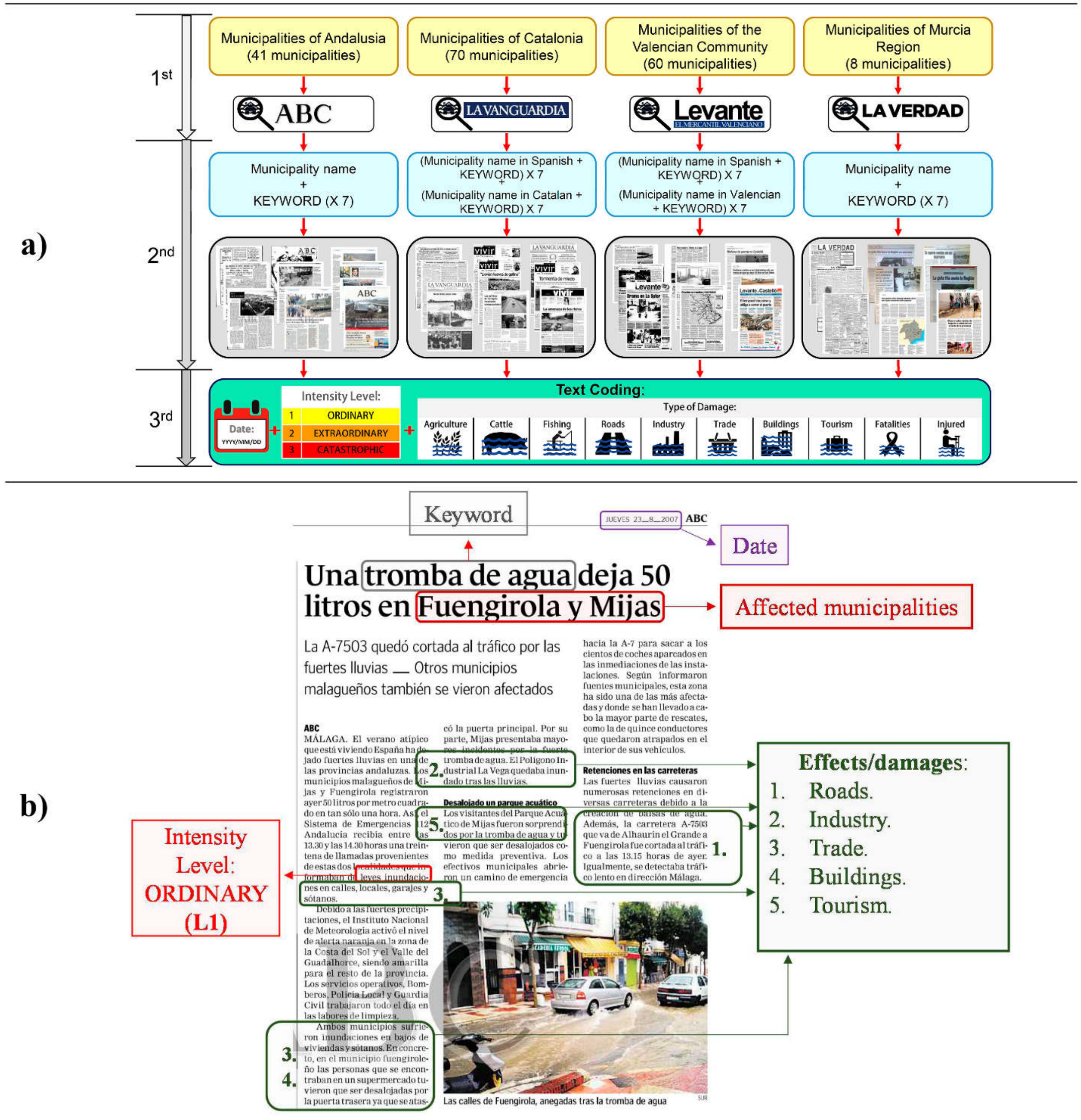


Figure 2: Method of cataloguing news, step by step (**Panel a**), and example of the coding system for the news (**Panel b**). Panel b source: ABC Newspaper, news of 23 August 2007.

Furthermore, some ancillary indices and variables have been calculated to characterize floods in the SMCM (see Table 2, Panel b). The severity index is the sum of damage quantity multiplied by flood intensity for each case, and it provides additional information. As an example, a flood of intensity 2 could produce major damage, but with concentrated effects in agriculture (Intensity = 2, severity index = 2); while a flood of intensity 1, could cause some weak damage but extend to a large number of sectors (for example, roads, tourism, commerce and agriculture) (Intensity = 1; severity index = 4 * 1 = 4). In other cases a flood could be very intense and also affect a large number of sectors, so its final impact is greater than if simply considering the intensity (for example, a flood of intensity 2 that affected roads, agriculture, tourism and trade would have a severity index of 8). Therefore, the severity index offers information that is complementary to the intensity level and the amount of damage.

With regard to the affected area, we have assigned to each flood the area of the municipality where it took place. While we are aware that a flood does not affect a whole administrative area, we consider it to be a good measure for performing comparative analyses at a spatiotemporal scale. Moreover, although a flood does not directly impact the whole municipality, the effects are felt indirectly throughout the administrative territory.

Finally, with the results of the SMC-Flood database, we have conducted a trend analysis to ascertain whether floods and their intensity have increased or decreased over time. The existence or absence of statistically significant trends was determined by the improved non-parametric test of Hirsch and Slack (1984), which is based on the Mann-Kendall range widely used in climatic and hydrological studies. This test gives information on two possible hypotheses: the null hypothesis (H0), indicating that the series does not present a significant trend; and the alternative hypothesis (Ha), indicating a statistically significant trend that may be negative or positive. The chosen level of significance is 95%. In addition, we calculated Sen´s Slope, which indicates the bias and size of this trend. Multiplying this value by the total number of observations, we would obtain an approximate value of the mean loss or gain of the variable over the time period.

4 Results

4.1 SMC-Flood records summary

According to the SMC-Flood database, the SMCM suffered 3,608 flood cases between the years 1960 and 2015. Of these, 72% were of an ordinary intensity (Level 1), less than 25% were extraordinary (Level 2), and slightly more than 3% were catastrophic (Level 3) (see Table 2, Panel a).

With regard to the types of damage (see Table 2, Panel a), roads (almost 80%) and homes (45%) were the variables most affected by floods. Trade and agriculture are also sectors that repeatedly suffer damage (in approximately 20% of cases). Tourism is another sector that suffers the impact of floods (16%). However, there are important differences in the types of damage, depending on the level of intensity. In general, the amount of damage increases with the level of intensity, meaning that the greater the intensity, the more assets and people that are affected. Between intensity Levels 1 and 2, the greatest increases occur among residential properties (almost 80% of the Level 2 floods involve damage to homes) and trade (almost half of Level 2 floods involve impact on trade). These two types of damage are interrelated insofar as the overflow of the water body affecting residential properties also affects trading establishments, which are generally located in the lower part of the buildings. Also notable are the increases in impacts on agriculture and trade. Regarding the changes between the damage produced in Level 3 floods and those of other levels, the most notable is the increase in the direct effects on people’s health (fatalities and injured). In fact, almost 100% of Level 3 cases involve human victims, such that the main criteria of the classification method consider that a flood having caused victims is a fundamental factor for considering it Level 3. In general, catastrophic floods are characterized by the fact that they affect the whole economic and social fabric of a community.

Regarding the affected area, in the SMCM, each flood affects 119 km^2. However, this value rises alarmingly as the intensity level of floods increases.

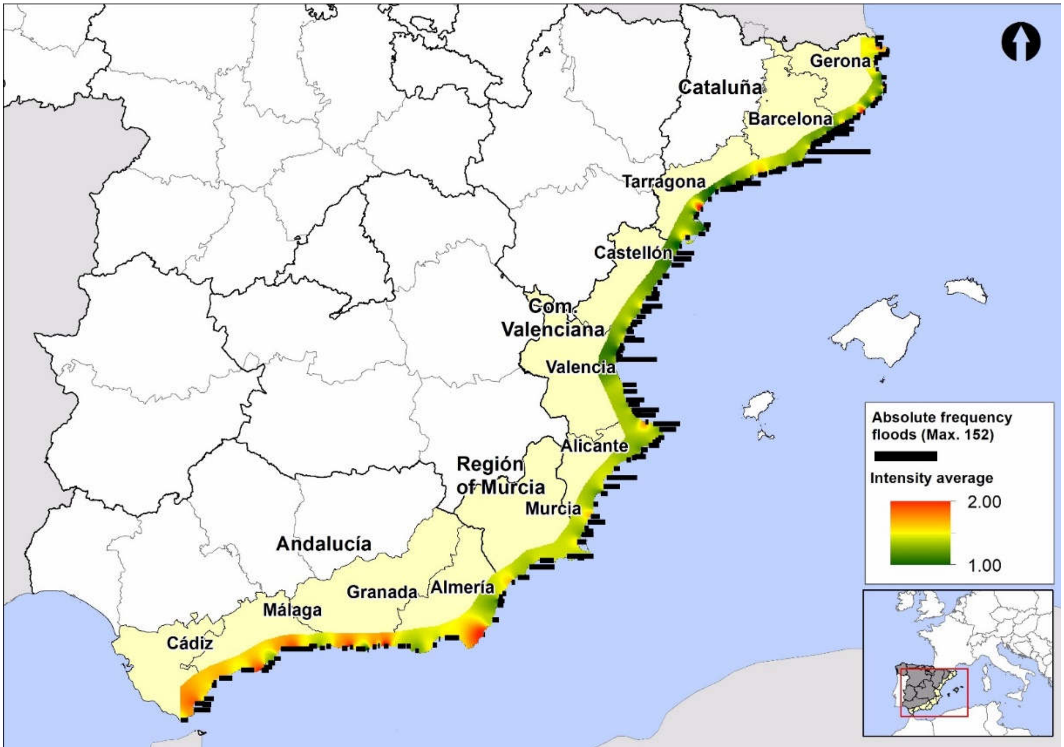
Table 2: SMC-Flood database summary.

		L1		L2		L3		TOTAL FLOOD CASES	
		N	%	N	%	N	%	N	%
	Cases	**2,599**	**72.03**	**887**	**24.58**	**122**	**3,38**	**3.608**	**100**
A)	**Agriculture.**	346	13.31	307	34.61	49	40.16	**702**	**19.46**
	Cattle.	10	0.38	33	3.72	13	10.66	**56**	**1.55**
	Fishing.	46	1.77	70	7.89	5	4.1	**121**	**3.35**
	Roads.	1,928	74.18	807	90.98	108	88.52	**2,843**	**78.8**
	Industry.	30	1.15	84	9.47	24	19.67	**138**	**3.82**
	Trade.	225	8.66	432	48.7	61	50	**718**	**19.9**
	Buildings.	850	32.7	697	78.58	82	67.21	**1,629**	**45.15**
	Tourism.	298	11.47	239	26.94	37	30.33	**574**	**15.91**
	Fatalities.	10	0.38	9	1.01	118	96.72	**137**	**3.8**
	Injured.	27	1.04	65	7.33	45	36.89	**137**	**3.8**
		L1		**L2**		**L3**		**TOTAL FLOOD CASES**	
B)	**Average Severity Index**		1.45		6.18		13.33		**2.57**
	Area (km^2)		115.86		118.04		181.48		**118.62**

*The different colours represent how the values deviate either above (red) or below (green) the 50th percentile (yellow) of the mean type of damage (**Panel a**) or the level of intensity (**Panel b**). ** The severity index is calculated as the intensity of a flood multiplied by the sum of the type of damage (sum of the dichotomous variables affected), divided by the number of floods (for each intensity level and for the total). Such that (Eq. 1): $\textbf{Severity Index} = (\sum(\boldsymbol{Intensity\ Level} \times \boldsymbol{Damages})) \div \boldsymbol{Intensity\ Level_N}$.

4.2 Spatial variability of floods

A detailed view at the municipal level reveals the existence of "hot spots" in the number and intensity of floods (see Fig. 3). Areas of high average intensity are found along most of the coast of Andalusia and, occasionally, in some sectors of the provinces of Gerona and Tarragona (for each municipality or province, the average intensity is the result of dividing the sum of the intensity levels of total floods by the total flood cases in this municipality or province). In fact, of the 20 municipalities with the highest average intensity, 12 are in Andalusia and 7 in Catalonia. Regarding the areas with the highest numbers of floods, it is necessary to differentiate between two types of areas: i) large urban conurbations (Barcelona, Valencia, Malaga and Alicante); and ii) coastal spaces that highly specialize in tourism (north of the province of Tarragona, in the province of Castellón, south of the province of Valencia, and north of the province of Alicante). However, the most outstanding aspect is an opposing latitudinal gradient: whilst the average intensity of floods increases as we go further south, their number increases in the opposite direction. Thus, considering the combination of intensity and frequency, the metropolitan area of Malaga stands out as the most threatened area.



CC.AA	Province	Pop. (2016)	Area (Km^2)	Density (Pop/Km^2)
	Gerona	243,098	666.2	365
Cataluña	*Barcelona*	2,573,798	477.7	5,388
	Tarragona	406,536	1,014.4	401
	Castellón	365,002	920.2	397
Comunidad Valenciana	*Valencia*	1,152,087	710.0	1,623
	Alicante	1,085,013	1,663.2	652
Región de Murcia	*Murcia*	463,260	2,948.0	157
	Almería	501,739	2,145.7	234
Andalucía	*Granada*	115,177	447.8	257
	Málaga	1,252,694	1,384.2	905
	Cádiz	254,886	1,003.4	254
Total:		**8,413,290**	**13,380.7**	**1,200**

Figure 3: Intensity average and total floods by municipality and Spanish Mediterranean coastal municipalities, spatial summary. The **map** shows in different colours the average intensity of floods in each municipality, and the black bars represent the total number of floods in each municipality.
The **table** reports the total population, the total area and the population density by province. The different colours represent how the values deviate above (from yellow to red colours) or below (from yellow to green colours) from the 50th percentile within the mean values of the variables (Pop., Area and Density). Source: INE, 2018.

Analysing the variability of the data aggregated at the provincial level confirms some of the spatial patterns detected (see Table 3). The average area affected by each flood is directly related to the differential size of the municipalities in each province. In this respect, it is appropriate to point out that the average size of the municipalities in the province of Murcia is larger, which is reflected in the fact that floods have a greater spatial impact in this province (each flood in Murcia affects an average of 574 km^2, compared to an average of 119 for the whole study area). As from the province of Alicante, a latitudinal change takes place in the form of floods affecting larger areas, which may also be due to climatic factors, governance, or the average size of the municipalities. On the other hand, the quantity of floods that occur in each province bears a direct relationship with the size and density of the exposed population (see Table in Fig. 3). This latter detail is especially important in the highly-developed provinces (Barcelona, Valencia and Alicante). These provinces, together with Castellón, are those that support a higher number of floods per kilometre of coastline; and they confirm the latitudinal gradient detected. This uneven N-S distribution is noticed in the intensity of floods, i.e., the further south we go, the higher the proportion of Level 2 and 3 floods, compared to Level 1. Likewise, this is evidenced by the severity index, the expression of which is even clearer. Therefore, we can affirm the existence of a spatial pattern in both intensity and damage moving in a southerly direction. In this regard, between the severity index and the latitudinal gradient (the provinces ordered correlatively from north to south), there is a Pearson correlation of 0.91 with a significance level of 95%. Furthermore, the correlation between the percentage of L1 floods and the latitudinal gradient is -0.81. For the L2 floods, the correlation is 0.73. Both cases have a significance level of 95%. This tendency may be related to the adoption of more efficient flood control measures in the northern provinces (the Catalonia and Valencia), owing to their early tourism and economic development. Likewise, an explanation can also be found in the climatic factor, as the rains are more torrential in the southern provinces (Martín-Vide, 2004). However, given the clear differences between provinces in the same autonomous community, we cannot avoid considering the economic and institutional factor, since other studies have detected growing institutional vulnerability following the aforementioned latitudinal gradient (López-Martínez et al., 2017).

Table 3: Spatial flood patterns in SMCM.

	CC.AA	Province	N-Flood cases	N%-Flood cases	% Province	Severity Index	Area (Km^2)	Flood cases/ Coast (Km^2)
Level 1	Cataluña	*Gerona*	165	6.35	70.51	1.32	30.60	0.63
		Barcelona	520	20.01	77.15	1.37	33.41	3.23
		Tarragona	257	9.89	79.81	1.36	49.31	0.92
	Comunidad Valenciana	*Castellón*	292	11.24	76.04	1.45	63.02	2.10
		Valencia	426	16.39	74.74	1.53	61.54	3.16
		Alicante	348	13.39	71.46	1.62	120.56	1.43
	Región. Murcia	*Murcia*	203	7.81	73.82	1.59	592.32	0.74
	Andalucía	*Almería*	117	4.50	71.34	1.41	150.34	0.47
		Granada	43	1.65	58.90	1.26	70.19	0.53
		Málaga	167	6.43	56.04	1.41	158.76	0.80
		Cádiz	61	2.35	48.03	1.26	198.21	0.74
	Total L1		**2,599**	**100.00**	**68.90**	**1.45**	**116**	**1.23**
Level 2	Cataluña	*Gerona*	63	7.10	26.92	5.37	30.97	0,24
		Barcelona	124	13.98	18.40	5.66	41.06	0,77
		Tarragona	55	6.20	17.08	6.15	41.56	0,20
	Comunidad Valenciana	*Castellón*	88	9.92	22.92	5.93	64.21	0,63
		Valencia	139	15.67	24.39	7.15	65.84	1,03
		Alicante	123	13.87	25.26	6.08	129.33	0,50
	Región. Murcia	*Murcia*	59	6.65	21.45	6.58	471.98	0,22
	Andalucía	*Almería*	38	4.28	23.17	6.37	169.91	0,15
		Granada	21	2.37	28.77	6.38	77.25	0,26
		Málaga	117	13.19	39.26	5.76	163.78	0,56
		Cádiz	60	6.76	47.24	6.77	159.67	0,73
	Total L2		**887**	**100.00**	**26.81**	**6.18**	**118**	**0.42**
Level 3	Cataluña	*Gerona*	6	4.92	2.56	11.50	29.54	0,02
		Barcelona	30	24.59	4.45	11.50	29.16	0,19
		Tarragona	10	8.20	3.11	12.90	47.54	0,04
	Com. Valenciana	*Castellón*	4	3.28	1.04	12.00	79.57	0,03
		Valencia	5	4.10	0.88	14.40	91.19	0,04
		Alicante	16	13.11	3.29	15.75	161.43	0,07
	Reg. Murcia	*Murcia*	13	10.66	4.73	17.54	758.69	0,05
	Andalucía	*Almería*	9	7.38	5.49	15.67	229.35	0,04
		Granada	9	7.38	12.33	12.67	53.41	0,11
		Málaga	14	11.48	4.70	10.29	260.10	0,07
		Cádiz	6	4.92	4.72	14.00	201.21	0,07
	Total L3		**122**	**100.00**	**4.30**	**13.33**	**181**	**0.06**
TOTAL Floods	Cataluña	*Gerona*	234	6.49	100.00	2.31	30.67	0,90
		Barcelona	674	18.68	100.00	2.22	34.63	4,19
		Tarragona	322	8.92	100.00	2.15	47.93	1,16
	Com. Valenciana	*Castellón*	384	10.64	100.00	2.28	63.46	2,76
		Valencia	570	15.80	100.00	2.59	62.85	4,22
		Alicante	487	13.50	100.00	2.77	124.12	2,00
	Reg. Murcia	*Murcia*	275	7.62	100.00	2.82	574.36	1,00
	Andalucía	*Almería*	164	4.55	100.00	2.72	159.21	0,66
		Granada	73	2.02	100.00	3.34	70.15	0,90
		Málaga	298	8.26	100.00	3.09	165.49	1,43
		Cádiz	127	3.52	100.00	3.80	180.15	1,55
	Total Flood cases:		**3,608**	**100.00**	**100.00**	**2.57**	**119**	**1.71**

N-Floods indicates the number of floods in each province between 1960 and 2015. *N%-Floods* reflects the percentage of the total floods that corresponds to each province. *% province* indicates the percentage of the total floods in each province that corresponds to each intensity level. *Severity index* reflects this value for each province and for each intensity level. *Area (km^2)* and *Floods/Coast (km^2)* show, respectively, for each province the km^2 affected and floods which, on average, affect each kilometre of coast. *The different colours represent how the values deviate, above (red) or below (green) from the average (yellow) of each variable (intensity level and total).

4.3 Seasonal flood variability over the SMCM

Floods that affect the SMCM have considerable seasonal variability with regard to number and intensity. As is to be expected from the climatic conditions (Barredo, 2007; Barrera-Escoda and Llasat, 2015), the majority of floods (58%) take place during the autumn months, especially in October as a result of the recurrent “cold pool” that affects the region. Furthermore, floods become more highly concentrated during this season as the intensity increases (55% of Level 1, 65% of Level 2 and 74% of Level 3). Therefore, autumn (September-November) is the season with the most danger of flooding in terms of both quantity and intensity. Autumn is followed by winter (December-February), summer (June-August) and finally spring (March-May) (Fig. 4 Panel a). However, there is little difference between the intensity of the autumn and winter floods (Fig. 4 Panel b) (mean intensity of 1.34 in the case of winter compared to 1.36 during the autumn).On the other hand, in spring and especially summer, the average intensities are lower (mean intensity of 1.22 and 1.16, respectively). The high intensity of the winter floods is probably related to the type of atmospheric situation that generates these floods and which usually leads to large accumulations of rainfall over several days (Muñoz-Diaz and Rodrigo, 2004). Related to this point, successive studies within this same project will analyse the climatic patterns in depth.

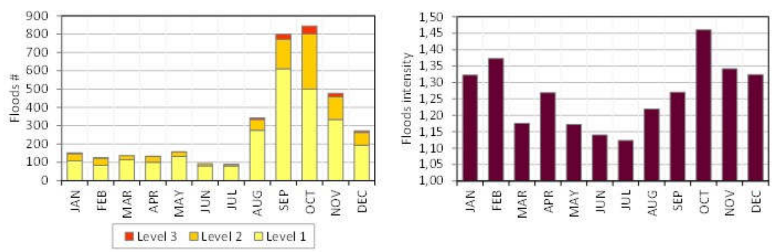


Figure 4: Monthly distribution of flood cases frequency and average intensity in SMCM.

This seasonal variability presents notable differences between provinces (see Fig. 5). Regarding the number of floods among the provinces of the east coast, the autumn seasonal pattern mentioned above is reinforced while in the southern provinces autumn becomes less prominent compared to winter, which is the season with a greater concentration of floods. This reveals a rainfall pattern associated with intense rains owing to the variability of the polar front (Muñoz-Diaz and Rodrigo, 2004), which especially affects the provinces in the south-west part of the study area. However, these provinces are also not exempt from being impacted by the frequent synoptic situations associated with the same easterly flow that affects the rest of the study area.

A similar spatial distribution can be observed in the average monthly intensity per province. In the provinces of Granada and Malaga, the autumn floods present the highest intensity values in the study area. However, unlike the frequency, the distribution pattern is less clear. The autumn and winter months coincide in more intense floods, mainly in the provinces between and including Castellón and Granada. However, in the provinces of Gerona and Cadiz, the mean intensity is higher in the winter months. Finally, in the provinces of Barcelona and Tarragona, late summer floods are also significantly frequent. This observation is consistent with those in previous works on these provinces (Llasat et al., 2013a, Gilabert and Llasat, 2018).

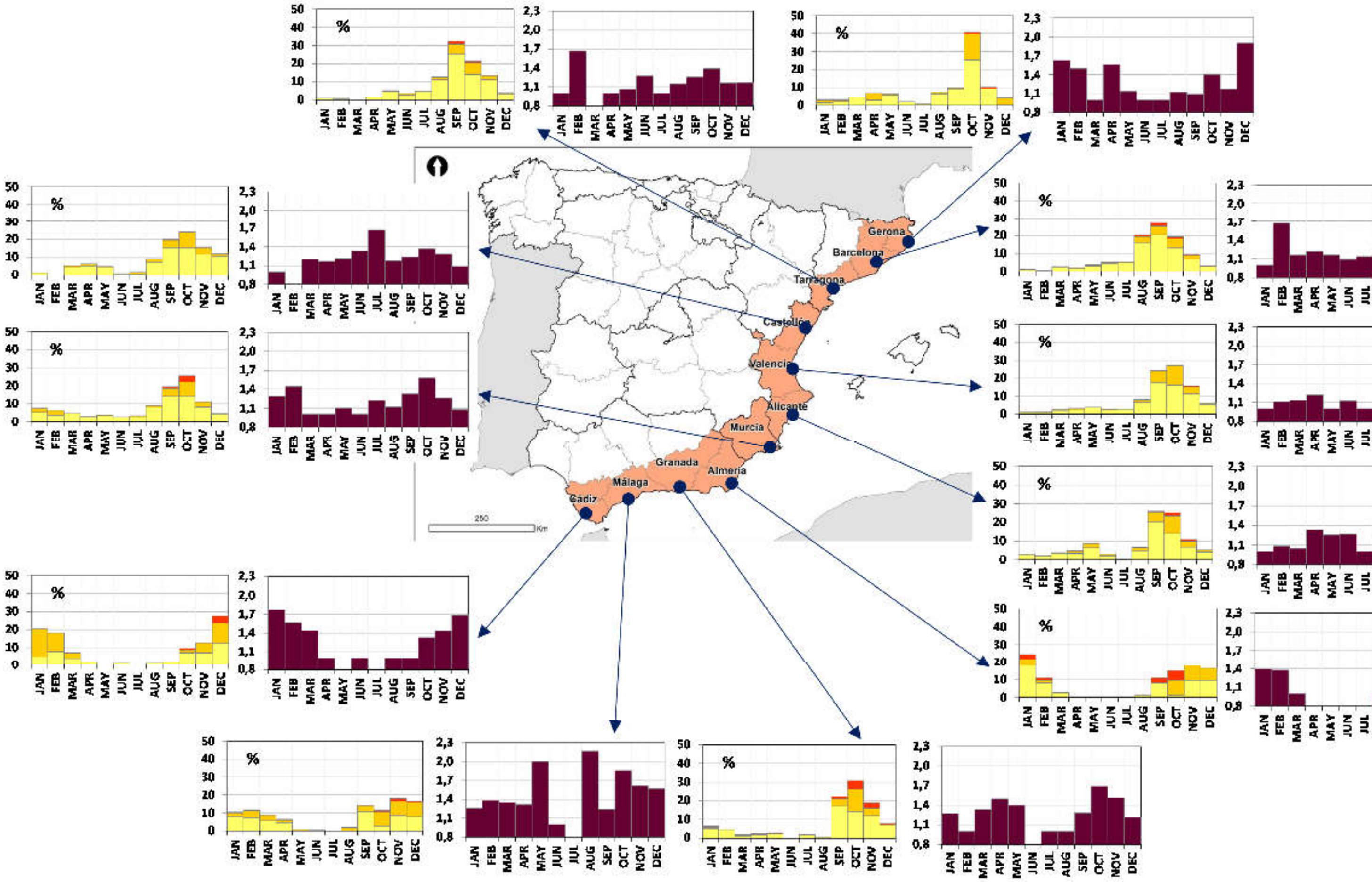


Figure 5: Spatial variability of flood cases frequency and average intensity in SMCM by province.

4.4 Type of damage variability

The type of damage also present notable spatial variability. With regard to the total amount of type of damage per province (Fig. 6, Panel a), the size of the exposed population is the main factor. In fact, the provinces with higher populations (Barcelona, Valencia and Alicante) are those that report a higher number of type of damage (Fig. 6, Panel a). However, if we consider the average quantity of type of damage reported per flood case by province, we observe that the average amount of type of damage increases in a north-south direction. In this way, the average amount of type of damage also shows a latitudinal gradient in a north-south direction. In other words, the provinces to the north of Valencia report an average amount of type of damage per flood that is lower than 2, while from Valencia towards the south this value is higher.

With regard to the different types of damage per province (Fig. 6, Panel b), the highest quantity of damages affects roads and buildings, the sum of which represents over 60% of all the type of damage reported. In the case of roads, riverbeds in the study area are for ephemeral purposes and therefore a large part of them can be crossed by roads without bridges or even used as communication routes between the headwater and mouth areas. Therefore, it is logical that most of the damages pertain to roads. Regarding damages to buildings, if we consider that floods are a natural risk that affect societies (Bates and Peacock, 1987, Tapsell, et al., 2002), damage to buildings is perceived to be one of the most significant impacts on societies (Nadal et al., 2009).

The provinces of Barcelona, Alicante and Malaga are highly developed and specialized in the service sector and tourism, which is why type of damage related to the primary sector are low. However, in the provinces of Tarragona, Almería and Granada, where the agricultural sector continues to have an important comparative economic weight, the type of damage in this sector are considerable.

Lastly, an analysis of the type of damage reveals the same latitudinal gradient, which this time is indicated by the record of injured persons and fatalities. As we head further south, there is an alarming increase in the percentages of these variables: from 3% on average between Gerona and Alicante to 6% between Murcia and Andalusia.

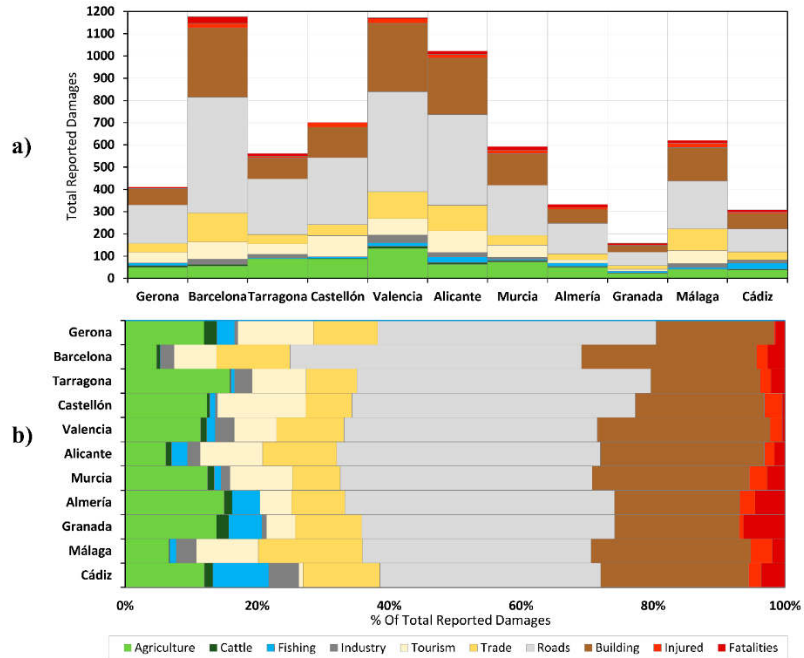


Figure 6: Types of damage by province.
Panel a shows the total types of damage per province. **Panel b** gives the damages per type, as a percentage of the total type of damage in each province.

4.5 Flood evolution and trends

The floods in the SMCM present an annual variability in frequency, impact and intensity that are closely related to the variation in the frequency and intensity of precipitations (Martin-Vide, 2004).

With regard to the annual mean intensity (see Fig. 7, Panel a) from 1960 to 1994, the data were more variable and extreme. In fact, the 10 years with greatest average intensity took place during that period. Furthermore, the five years of highest mean intensity were, respectively: 1973, 1987, 1962, 1965 and 1961. However, it is important to emphasize that the mean annual intensity presents a statistically significant negative trend, i.e., the average intensity of floods descends during the period analysed. Likewise, even though the severity index during the first five years of the nineteen-sixties was particularly high, their average annual value also presents a significant negative trend. According to the severity index rank, the following years should be highlighted: 1973, 1962, 1987, 1982 and 1964. Some of the highlighted years coincide with the most catastrophic floods occurring in the study area (1973, 1962 and 1987) in the last century.

With regard to the annual frequency of floods (see Fig. 7, Panel b), an increase is observed since the eighties and, especially, since 1996. Since then, the number of floods for the majority of years is above average. The trend analysis detects a statistically significant positive trend, which reveals that every year floods increase by 2.3% compared to their average value. However, this increase is not homogenous according to the intensity level because the Level 1 and Level 2 floods present significant positive trends while those of Level 3 either remain stable or have no appreciable trend. The rising trend is more pronounced in the case of the Level 1 floods, which have an annual increase of 2.8% compared to 1.1% in the case of Level 2 floods.

Turco and Llasat (2011) and Llasat et al., (2010), have also found that flood trends over recent decades in Catalonia are due mainly to an increase in urbanization in flood-prone areas near torrential and non-permanent streams.

Lastly, the evolution of the affected area presents variability that is similar to the frequency behaviour of floods (see Fig. 7, Panel c). The decade of the nineteen-eighties coincides with the time when values began to increase. Especially outstanding as disastrous periods are the second half of the nineteen-eighties and the decade of the 2000s. However, it is necessary to point out some nuances and differentiations. The total values for the affected area have a positive trend, but if we consider the size of the area affected according to intensity levels, a significant positive trend is detected only for Level 1 floods. That is, every year the area affected by floods increases by 166 km^2 (an increase of 2.2%). This situation becomes especially notable in the case of Level 1 floods, for which the new area affected is 158 km^2 per year (a growth rate of 2.9%).

During the comparable data period (1971-2015), the flood damage database on insured assets of the National Insurance Consortium of Spain (NISS) (Consorcio de Compensación de Seguros, 2019) also shows a positive trend in floods. In this case, it is evidenced by an increase in the annual amount of type of damage filed, i.e., in the amount of money indemnified. In addition, peaks in the amount of money indemnified detected in the NISS database coincide with the flood cases and impact peaks detected in our data base (1987, 1989, 1997 and 2007). On the other hand, the NISS database coincides with our database in indicating the most dangerous months for floods (mainly September and October). However, the different characteristics between these two databases lead to incomparable results from and utility of both databases comparable. While the NISS database offers aggregated data at the provincial level and refers only to the number of procedures for economic impacts and losses, the SMC-Flood database offers data at the municipal level for the Mediterranean coast and it refers to flood intensity, severity and type of impact. On the other hand, it should be noted that the Spanish insurance contract does not require insuring one’s home. Therefore, this database could be even more biased than ours, depending on the degree of insurance coverage in the municipalities of the study area (Clavero, 2016). On the other hand, because the National Insurance Consortium database is based on private insured assets, we have limited information on the impact of floods on public goods such as roads. In this respect, and taking into account the great weight that road damages have in our database, it is not surprising that the SMC-Flood database considers a number of cases far greater than that of the National Insurance Consortium database.

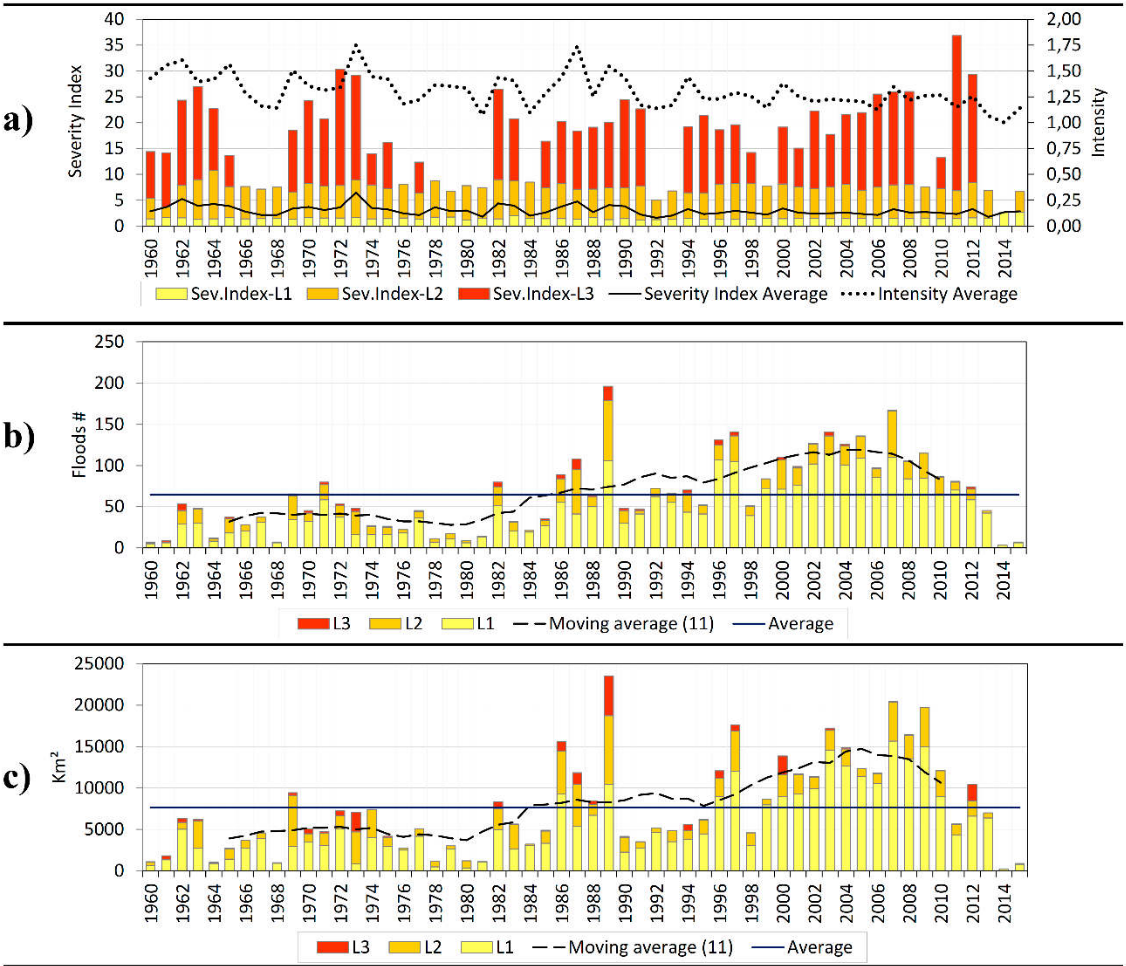


Figure 7: Temporal variability of the intensity, severity and spatial impact of floods cases in the SMCM.
The values indicate the annual accumulation per intensity level. The mobile mean of 11 years has been added to temper the variability, as well as the total mean of each variable, in order to identify years with values above or below the mean.
Panel a indicates the variability of the annual intensity and severity of floods. **Panel b** indicates the variability of the annual number of floods. Finally, **Panel c** indicates the variability of the area affected.

Related to the positive trend observed in the data, Llasat et al. (2016) pointed out that it may be due to the following main factors: i) climatic issues (a greater recurrence of torrential rain events in the study area); and ii) the increase in exposure and vulnerability due to the increase in population and economic growth.

Due to the fact that L1 floods concern not only river floods but also flash floods and in situ floods, the increase in exposure could take on more importance as the exposed surface in flood-prone areas becomes greater. Thus it is necessary to include the growing surface outside the floodplain (Pérez-Morales et al., 2018), for which the evidence indicates that L1 floods have the most clear upward trends.

However, there are other factors that should not be overlooked or dismissed. According to Llasat et al., 2009, it is important to consider that trends may be biased by: i) public opinion having greater sensitivity or perception towards natural risks due to increased newspaper coverage of floods; ii) a greater spatial coverage of the news as a result of improved communications. Eisensee and Strömberg (2007) also argue that the coverage of natural disasters in the press depends on the availability of other newsworthy material at the time of the disaster. Additionally, there may be some spatial bias in the news based on the newspaper's spatial coverage (Walmsley, 1980). In this regard, the newspapers used in the SMC-Flood database are regional newspapers, which specifically cover the information on each autonomous community analysed throughout the study period. On the other hand, Llasat et al. (2009) show that the subjectivity of the journalist or newspaper can bias the flood intensity level, but not the type of damage. In this regard, the type of damage may be under-documented, but it can rarely be over-documented. However, population increase in the SMCM has been able to influence the increase in flood news for small populations. However, this last point does not imply a methodological bias. On the contrary, the positive correlation between population increase and increase in the number of floods shows that the increase in exposure is mainly responsible for the trends observed in the study area's floods. These results are in line with other works (Pérez-Morales et al., 2018) and are consistent with the general theory of risk, which postulates that risk is a social construction (Bates and Peacock, 1987; Tapsell, et al., 2002), and therefore the occurrence of a natural risk depends on their being an exposed population susceptible to suffering an impact.

The positive correlation between population increase and increase in the number of flood cases can be observed when we analyse the flood trends according to population growth. In making this analysis, we observed that the greater the population increase in the municipalities between 1960 and 2011 (the two extreme census years of the study period), the greater the significance and intensity of the trend. In the following table (Table 4), it can be observed that no significant trend in flood cases exists for the set of municipalities where population have grown less than 50% between 1960 and 2011. However, floods have a statistically significant trend in municipalities that have grown more than 50%. The interesting thing is that the rate of increase in floods becomes greater as population growth becomes greater. In spite of all the above, the social factors involved in flood processes generate such complexity that we are unable to rule out the abovementioned possible biases in the observed trends.

Table 4: Flood cases trends in Spanish Mediterranean coastal municipalities in relation to ranges of population increase between 1960 and 2011.

Population increase range in %	Kendall's tau	P-value	Sen´s Slope
Less than 0%	-0.048	0.733	0
Between 0 and 50%	-0.060	0.550	0
More than 50 and less than 100%	0.280	0.005	0.127
More than 100 and less than 200%	0.340	0.000	0.286
More than 200 %	0.380	< 0,0001	0.471

Note: To calculate trends, we used Hirsch and Slack's nonparametric test (1984), which is based on the Mann-Kendall range. The trial version of XLSTAT software (Addinsoft, 2018) was used to calculate it. The Mann-Kendall test provides a level of statistical significance (p-value). The chosen threshold of significance was 95%, which indicates that p-values above 0.05 should lead to rejecting the hypothesis of a trend in the series. When the p-value is less than 0.05, the trend can be positive or negative. Sen´s Slope shows the annual change rate in floods. That is, the value indicates the annual increase or decrease of floods.

5 Conclusions

In this paper we present the initial results of the SMC-Flood database for the Spanish Mediterranean coastal municipalities between 1960 and 2015. This database provides information on local flood cases with information on affected area, intensity, severity and type of damage. The results have enabled reconstructing 3,008 flood cases that affected all the municipalities studied during the last 55 years.

Exploiting the database has made it possible to obtain a series of values that provide evidence of trends which reveal the socio-environmental dynamic. In this respect, the type of damage show that the major impacts occur on roads, buildings, agriculture and trade. Furthermore, the average area affected per flood is 119 km^2. In general, the months that pose the greatest hazard with regard to the number of floods and their intensity are the autumn months, although the winter is also a highly hazardous season.

The detailed spatial analysis has allowed us to identify a series of black spots where the intensity of floods and the amount of damage are very high (especially on most of the coast of Andalusia and in some areas of Gerona and Tarragona). Furthermore, there are places with large populations that are exposed, which in turn determines a high recurrence of floods.

However, our main contribution lies in establishing the presence of a clear latitudinal gradient that is characterized by more severe, intensive, extensive and damaging floods as we move from north to south. This spatial inequality is foreseeably explained by greater deficiencies in the spatial planning of the provinces in the south, although the climatic and orographic factors cannot be ruled out. Under these circumstances the southern areas are the places in need of the best adaptation plans, especially when taking into account that these provinces are also subject to a greater risk of mortality associated with floods.

Lastly, it is important to highlight that the intensity and mean annual severity of floods have begun to follow a statistically significant negative trend. That is, on average, floods tend towards lower intensity and severity. However, the annual frequency and average area affected by floods has experienced a positive trend. Nonetheless, this increase is not homogenous according to intensity level, because Level 1 and Level 2 floods present significant positive trends while those of Level 3 remain stable. In this respect, a paradox is revealed: although it is certainly positive that the most catastrophic flooding are not increasing, the society has become used to a larger frequency and area affected by flooding, even though the current flood management tools (structural and non-structural) could avoid them.

As a final conclusion, the positive trends in the number of flood cases are highly correlated with the increase in the exposed population. Nevertheless, the complexity of social factors involved in flood processes impedes us from ruling out possible biases in the observed trends. Therefore, deeper knowledge is needed on the climatic, geographic and socioeconomic variables involved in flood processes. This will be the objective of successive research projects.

Acknowledgements. We thank the newspapers LV and ABC for their open data access policy. Special thanks to the newspapers LVM and EMV for collaborating on this research project by allowing free access to their databases. This work has been partially supported by the Spanish Ministry of Economy and Innovation (CGL2016-75996-R). Thanks also to

Interuniversity Institute of Geography for their financial support. SG-G acknowledges the support of the Spanish Ministry of Science, Innovation and Universities through the “Juan de la Cierva-Incorporación” grant (IJCI-2016-29016).

Competing interests. The authors declare that they have no conflict of interest.

Data availability. The systematic data of the SMC-Flood database are not publicly accessible because they are currently being used in an ongoing research project. Aggregate data at the provincial level can be obtained by request addressed to the corresponding author.

References

Aceituno P., Prieto M.R., Solari M.E., Martínez A., Poveda G., Falvey M.: The 1877–1878 el Niño episode: Associated impacts in South America, Climatic Change, 92(3-4): 389-416, 2009.

Addinsoft, S. A.: XLSTAT software, available at: http://www.xlstat.com/es/, last access: 23 February 2019.

Adhikari, P., Hong, Y., Douglas, K. R., Kirschbaum, D. B., Gourley, J., Adler, R., and Brakenridge, G. R.: A digitized global flood inventory (1998–2008): compilation and preliminary results, Natural Hazards, 55(2), 405-422, 2010.

Ashley, S. T., ang Ashley, W. S.: Flood fatalities in the United States, Journal of Applied Meteorology and Climatology, 47(3), 805-818, 2008.

Barnolas, M. and Llasat, M. C.: A flood geodatabase and its climatological applications: the case of Catalonia for the last century, Nat. Hazards Earth Syst. Sci., 7, 271–281, doi:10.5194/nhess-7- 271-2007, 2007.

Barredo, J. I., Saurí, D., and Llasat, M. C.: Assessing trends in insured losses from floods in Spain 1971–2008, Natural Hazards and Earth System Sciences, 12(5), 1723-1729, 2012.

Barredo, J. I.: Major flood disasters in Europe: 1950–2005, Natural Hazards, 42(1), 125-148, 2007.

Barriendos, M., Coeur, D., Lang, M., Llasat, M. C., Naulet, R., Lemaître, D., and Barrera, A. : Stationarity analysis of historical flood series in France and Spain (14th–20th centuries), Natural Hazards and Earth System Science, 3(6), 583-592, 2003.

Barriendos, M., Ruiz Bellet, J. L., Tuset Mestre, J., Mazón Bueso, J., Balasch Solanes, J. C., Pino González, D., and Ayala, J. L.: The"Prediflood" database of historical floods in Catalonia (NE Iberian Peninsula) AD 1035–2013, and its potential applications in flood analysis, Hydrology and Earth system sciences, 18, 4807-4823, 2014.

Bates, F. L., and Peacock, W.G.: Disasters and Social Change. In R.R. Dynes, B. Demarchi and C. Pelanda (eds.): The Sociology of Disasters. Franco Angeli Press, Milan, 1987.

Bouwer, L. M.: Have disaster losses increased due to anthropogenic climate change?, Bulletin of the American Meteorological Society, 92(1), 39-46, 2011.

Brakenridge, G.R.: Global Active Archive of Large Flood Events, Dartmouth Flood Observatory, University of Colorado, available at: http://floodobservatory.colorado.edu/Archives/index.html (last access: 12th May 2018), 2010.

Brázdil, R., Chromá, K., Řezníčková, L., Valášek, H., Dolák, L., Stachoň, Z., ... and Dobrovolný, P.: The use of taxation records in assessing historical floods in South Moravia, Czech Republic, Hydrology and Earth System Sciences, 18(10), 3873-3889, 2014.

Camuffo, D., and Enzi, S.: The analysis of two bi-millennial series: Tiber and Po river floods. In Climatic Variations and Forcing Mechanisms of the last 2000 years (pp. 433-450). Springer, Berlin, Heidelberg, 1996.

Clavero, B. S.: Estadística de la cobertura de los riesgos extraordinarios en España por parte del Consorcio de Compensación de Seguros, Revista de Estadística y Sociedad, 67, 19-25, 2016.

Consorcio de Compensación de Seguros: Estadística de Riesgos Extraordinarios. Serie 1971-2018, Ministerio de Economía y Empresa, Madrid, 2019.

Diakakis, M., Mavroulis, S., and Deligiannakis, G.: Floods in Greece, a statistical and spatial approach, Natural hazards, 62(2), 485-500, 2012.

Eisensee, T., & Strömberg, D.: News droughts, news floods, and US disaster relief. The Quarterly Journal of Economics, 122(2), 693-728, 2007.

EM-DAT: The OFDA/CRED International Disaster Database, Brussels, Belgium: Université Catholique de Louvain, available at: http://www.emdat.be (last access: 5th September 2018), 2018.

ESSL-European Severe Storms Laboratory: ESWD (European Severe Weather Database), available at: http://www.eswd.eu/ (last access: 17th October 2018), 2018.

European Enviromental Agency: European past floods, available at: https://www.eea.europa.eu/data-and-maps/data/european-past-floods#tab-figures-produced (last access: 6th July 2018), 2018.

FitzGerald, G., Du, W., Jamal, A., Clark, M., and Hou, X. Y.: Flood fatalities in contemporary Australia (1997–2008), Emergency Medicine Australasia, 22(2), 180-186, 2010.

Gilabert, J., & Llasat, M. C.: Circulation weather types associated with extreme flood events in Northwestern Mediterranean. *International Journal of Climatology*, *38*(4), 1864-1876, 2018.

Gil-Guirado S.: Reconstrucción climática histórica y análisis evolutivo de la vulnerabilidad y adaptación a las sequías e inundaciones en la Cuenca del Segura (España) y en la Cuenca del Río Mendoza (Argentina), Cuadernos Geográficos, 52(2): 132-151, 2013.

Gil-Guirado, S., Espín-Sánchez, J. A., and Prieto, M. D. R.: Can we learn from the past? Four hundred years of changes in adaptation to floods and droughts. Measuring the vulnerability in two Hispanic cities, Climatic change, 139(2), 183-200, 2016.

Glaser, R., and Stangl, H.: Climate and floods in Central Europe since AD 1000: data, methods, results and consequences, Surveys in Geophysics, 25(5-6), 485-510, 2004.

Guzzetti, F., Stark, C. P., and Salvati, P.: Evaluation of flood and landslide risk to the population of Italy, Environmental Management, 36(1), 15-36, 2005

Hilker, N., Badoux, A., and Hegg, C.: The Swiss flood and landslide damage database 1972-2007, Natural Hazards and Earth System Sciences, 9(3), 913, 2009.

Hirsch, R. M. and Slack, J. R.: A nonparametric trend test for seasonal data with serial dependence, Water Resources Research, 20(6), 727-732, 1984.

Instituto Nacional de Estadística (INE): Demografía y Población, available at: https://www.ine.es/dyngs/INEbase/es/categoria.htm?c=Estadistica_P&cid=1254734710984 (last access: 6th October 2018), 2018.

Jongman, B., Koks, E. E., Husby, T. G. and Ward, P. J.: Financing increasing flood risk: evidence from millions of buildings, Natural Hazards and Earth System Science Discussions, 2, 137-165, 2014.

Jongman, B., Winsemius, H. C., Aerts, J. C., de Perez, E. C., van Aalst, M. K., Kron, W., and Ward, P. J.: Declining vulnerability to river floods and the global benefits of adaptation, Proceedings of the National Academy of Sciences, 112(18), E2271-E2280, 2015.

Koks, E. E., Jongman, B., Husby, T. G., and Botzen, W. J.: Combining hazard, exposure and social vulnerability to provide lessons for flood risk management, Environmental science & policy, 47, 42-52, 2015.

Kundzewicz, Z. W., Pińskwar, I., and Brakenridge, G. R.: Large floods in Europe, 1985–2009, Hydrological Sciences Journal, 58(1), 1-7, 2013.

Llasat, C., Llasat-Botija, M., Petrucci, O., Pasqua, A. A., Rossello, J., Vinet, F., & Boissier, L.: Floods in the north-western Mediterranean region: presentation of the HYMEX database and comparison with pre-existing global databases. *La Houille Blanche*, (1), 5-9, 2013b.

Llasat, M. C., Barriendos, M., Barrera, A., and Rigo, T.: Floods in Catalonia (NE Spain) since the 14th century. Climatological and meteorological aspects from historical documentary sources and old instrumental records, Journal of hydrology, 313(1-2), 32-47, 2005.

Llasat, M. C., Llasat-Botija, M., and López, L.: A press database on natural risks and its application in the study of floods in Northeastern Spain, Natural Hazards and Earth System Sciences, 9, 2049-2061, 2009.

Llasat, M. C., Llasat-Botija, M., Petrucci, O., Pasqua, A. A., Rosselló, J., Vinet, F., & Boissier, L. : Towards a database on societal impact of Mediterranean floods within the framework of the HYMEX project. *Natural Hazards and Earth System Sciences*, *13*(5), 1337-1350, 2013a.

Llasat, M. C., Llasat-Botija, M., Rodriguez, A., and Lindbergh, S.: Flash floods in Catalonia: a recurrent situation, Adv. Geosci., 26, 105–111, 2010.

Llasat, M. C., Marcos, R., Turco, M., Gilabert, J., & Llasat-Botija, M.: Trends in flash flood events versus convective precipitation in the Mediterranean region: The case of Catalonia. *Journal of Hydrology*, *541*, 24-37, 2016.

López-Martínez, F., Gil-Guirado, S., and Pérez-Morales, A.: Who can you trust? Implications of institutional vulnerability in flood exposure along the Spanish Mediterranean coast, Environmental Science & Policy, 76, 29-39, 2017.

Martín, M. L., Santos-Muñoz, D., Morata, A., Luna, M. Y., and Valero, F.: An objectively selected case study of a heavy rain event in the Mediterranean Basin: A diagnosis using numerical simulation, Atmospheric research, 81(3), 187-205, 2006.

Martín-Vide, J.: Spatial distribution of a daily precipitation concentration index in peninsular Spain, International Journal of Climatology, 24(8), 959-971, 2004.

McEwen, L. J.: Flood seasonality and generating conditions in the Tay catchment, Scotland from 1200 to present, Area, 38(1), 47-64, 2006.

Munich Re: NatCat SERVICE Loss Database for Natural Catastrophes Worldwide, available at: http://www.munichre.com/en/reinsurance/business/non-life/georisks/natcatservice/default.aspx (last access: 30th July 2018), 2018.

Muñoz-Diaz, D. and Rodrigo., F. S.: Spatio-temporal patterns of seasonal rainfall in Spain (1912-2000) using cluster and principal component analysis: comparison, Annales Geophysicae, European Geosciences Union, 22 (5), 1435-1448, 2004.

Nadal, N. C., Zapata, R. E., Pagán, I., López, R., & Agudelo, J.: Building damage due to riverine and coastal floods. Journal of Water Resources Planning and Management, 136(3), 327-336, 2009.

Napolitano, E., Marchesini, I., Salvati, P., Donnini, M., Bianchi, C., and Guzzetti, F. LAND-deFeND–An innovative database structure for landslides and floods and their consequences, Journal of environmental management, 207, 203-218, 2018.

NOOA: (2018). Storm Events Database, available at: https://www.ncdc.noaa.gov/stormevents/ftp.jsp (last access: 24th July 2018), 2018.

Olcina Cantos, J., Hernández Hernández, M., Rico Amorós, A. M., and Martínez Ibarra, E.: Increased risk of flooding on the coast of Alicante (Region of Valencia, Spain), Natural Hazards and Earth System Sciences, 10(11), 2229-2234, 2010.

Pagán, J. I., Aragonés, L., Tenza-Abril, A. J., and Pallarés, P.: The influence of anthropic actions on the evolution of an urban beach: Case study of Marineta Cassiana beach, Spain, Science of the Total Environment, 559, 242-255, 2016.

Papagiannaki, K., Lagouvardos, K., and Kotroni, V.: A database of high-impact weather events in Greece: a descriptive impact analysis for the period 2001–2011, Nat. Hazards Earth Syst. Sci., 13, 727-736, https://doi.org/10.5194/nhess-13-727-2013, 2013.

Pascual, G., and Bustamante, A.: Catálogo Nacional de Inundaciones Históricas. Actualización. Ministerio del Interior: Madrid, Spain, 2011.

Pérez-Morales, A., Gil-Guirado, S., and Olcina-Cantos, J.: Housing bubbles and the increase of flood exposure. Failures in flood risk management on the Spanish south-eastern coast (1975–2013), Journal of Flood Risk Management, 11, S302-S313, 2018.

Petrucci, O., Aceto, L., & Aurora Pasqua, A.: Long-term analysis of Damaging Hydrogeological Events in Calabria (Southern Italy). In *EGU General Assembly Conference Abstracts* (Vol. 20, p. 7899), 2018.

Polemio, M., and Petrucci, O.: The occurrence of floods and the role of climate variations from 1880 in Calabria (Southern Italy), Natural Hazards and Earth System Sciences, 12 (1), 129-142, 2012.

Quan, R.: Risk assessment of flood disaster in Shanghai based on spatial–temporal characteristics analysis from 251 to 2000, Environmental earth sciences, 72(11), 4627-4638, 2014.

Romero, R., Doswell III, C. A., and Ramis, C.: Mesoscale numerical study of two cases of long-lived quasi-stationary convective systems over eastern Spain, Monthly Weather Review, 128(11), 3731-3751, 2000.

Salvati, P., Marchesini, I., Balducci, V., Bianchi, C., and Guzzetti, F. : A new digital catalogue of harmful landslides and floods in Italy. In Landslide science and practice (pp. 409-414). Springer, Berlin, Heidelberg, 2013.

Sumner, G. N., Romero, R., Homar, V., Ramis, C., Alonso, S., and Zorita, E.: An estimate of the effects of climate change on the rainfall of Mediterranean Spain by the late twenty first century, Climate Dynamics, 20(7-8), 789-805, 2003.

Swiss Re: Sigma Natural Catastrophes and Man-made Disasters, available at: http://institute.swissre.com/research/overview/sigma/ (last access: 27th September 2018), 2018.

Tapsell, S. M., Penning-Rowsell, E. C., Tunstall, S. M., and Wilson, T. L.: Vulnerability to flooding: health and social dimensions. Philosophical transactions of the royal society of London. Series A: Mathematical, Physical and Engineering Sciences, 360(1796), 1511-1525, 2002.

Terti, G., Ruin, I., Anquetin, S., and Gourley, J. J.: A situation-based analysis of flash flood fatalities in the United States, Bulletin of the American Meteorological Society, 98(2), 333-345, 2017.

Trigo, R. M., and Palutikof, J. P.: Precipitation scenarios over Iberia: a comparison between direct GCM output and different downscaling techniques, Journal of Climate, 14(23), 4422-4446, 2001.

Turco, M. and Llasat, M. C.: Trends in indices of daily precipitation extremes in Catalonia (NE Spain), 1951–2003, Nat. Hazards Earth Syst. Sci., 11, 3213–3226, doi:10.5194/nhess-11-3213- 2011, 2011.

Vennari, C., Parise, M., Santangelo, N., and Santo, A. : A database on flash flood events in Campania, southern Italy, with an evaluation of their spatial and temporal distribution, Natural Hazards and Earth System Sciences, 16(12), 2485-2500, 2016.

Walmsley, D. J.: Spatial bias in Australian news reporting. Australian Geographer, 14(6), 342-349, 1980.

WMO, UCL: Atlas of mortality and economic losses from weather, climate and water extremes 1970–2012, Geneva, Switzerland: World Meteorological Organization (WMO), 2014.

Zêzere, J. L., Pereira, S., Tavares, A. O., Bateira, C., Trigo, R. M., Quaresma, I., ... and Verde, J.: DISASTER: a GIS database on hydro-geomorphologic disasters in Portugal, Natural Hazards, 72(2), 503-532, 2014.