Floods in the Pyrenees: A global view through a regional database, by María Carmen Llasat, Montserrat Llasat-Botija, Erika Pardo, Raül Marcos-Matamoros, Marc Lemus-Canovas, submitted to NHESS journal

Answers to the referees and revised paper with track changes

Dear authors,

Your article has been revised by two reviewers who proposed a major review. You provided a suitable reply. From my side i reccomend moderate-to-major reviews. Please provide the manuscript corrected with suggested comments. I will speed up the process during the second stage of review.

Best regards

Paolo Tarolli

NHESS Executive Editor

Dear Paolo

Thank you very much for agreeing to be the editor of this article and for the time you are dedicating to it. We are aware of the increasing difficulties that come with being an editor. We have made big changes to our article following the reviewers' suggestions. We hope to have responded to your comments and consider that the article has improved substantially.

Thank you again

Prof. Maria Carmen Llasat in behalf all the co-authors

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Answers to Review 1

> The paper "Floods in the Pyrenees: A global view through a regional database" shows the analysis on the first systematic dataset of flood episodes referred to the Pyrenees massif, named PIRAGUA_flood, concerning the period 1981-2015. The topic is very important, and the paper fill a gap for a wide area including regions of different countries.

Dear reviewer,

Above all, we want to express our acknowledgement for the time spent reviewing this paper. We have carefully considered all your comments, as well as those from the other reviewer, and have implemented substantial revisions to the paper. We are confident that these changes have significantly enhanced the quality of our work. In order to facilitate you the revision we have chosen to introduce here those paragraphs, figures and tables that have been significantly modified or that are new.

We would like to thank you again for your helpful feedback and availability to review this paper.

Maria Carmen Llasat on behalf of all the authors

1. Nevertheless, I think that the paper is not ready for publication, it must be strongly reviewed and better addressed. As is, it seems a folder containing scattered notes without a clear goal to reach. I suggest to select a series of goals, declare them at the beginning, and try to reach them, even if this mean that some of the paragraph must be eliminated. Currently there are a series of points but no one of them is analyzed deeply.

Thank you very much for your comments, which have been very useful for us to improve the article and make major changes. According to them, the text of the paper as well as the figures and tables have been considerably modified. The new references that have been added to the article have also been included in this letter.

In response to your comment, the Introduction has been substantially modified as you can see in the answer to your comment number 4. The final objective of the paper is the presentation of the database on flood events in the Pyrenees, PIRAGUA_flood, that we have made available to the public, to analyze the trends in light of the most recent articles (Clavera-Gispert et al., 2023), and characterize the weather types favourable to these flood events. In order that a database like this can be reproduced anywhere else and to show the rigor that sustains it, the first part of the paper focuses on the detailed presentation of the methodology and criteria that have been used. The second part offers the first approximation to the knowledge of the floods in the entire Pyrenean region, their spatio-temporal distribution, types of weather and trends. In the revised version of the article, a proposal for adaptation measures against floods in the study area has been introduced into the discussion.

This type of article is in line with others already published by NHESS, such as those by Llasat et al. (2013), Papagiannaki et al. (2013), or Gil-Guirado et al. (2019). The journal Natural Hazards has also published articles along these lines, such as that of Zêzere et al. (2014).

2. The database is updated to 9 years ago! It seems very strange, especially because the Authors are interested to analyze temporal distribution of the events, and an old series does not allow to evaluate the recent tendencies, especially in the light of climate change. I think that this is the large obstacle to the publication of the paper.

We agree with your comment and that is why we consider that a clarification is necessary. This database was created in the context of the European Interreg PIRAGUA project, which began in 2018 and ended in 2021. The database began to be created at the beginning of the project and it was considered appropriate to finish it in 2015 because this provided a period of 35 years, which was considered sufficiently representative. On the other hand, the period ending in 2015 is consistent with the one analyzed in terms of flow trends, within the PIRAGUA project itself, and temperature and precipitation, within the CLIMPY project. An example is the paper from Clavera-Gispert (2023), where they have analysed the streamflow trends of the Pyrenees using the same period (1980-2015). The flood database presented here has recently been included in the publications of Beguería et al. (2023a, 2023b), and has been made available to the public both through the OPCC Geoportal (https://www.opcc-ctp.org/en/geoportal) and the CSIC repository (http://hdl. handle.net/10261/270351). These publications have also allowed us to improve the discussion in this article about precipitation and flow trends.

As I have already mentioned, our objective is to present a database that we have made available to other researchers and anyone interested, and to approach for the first time the knowledge of floods in a mountain massif such as the Pyrenees, to which until now there were only partial studies referring to specific events or locations. A period of 35 years is sufficient for this characterization, as well as to talk about trends. However, as you say, it is not enough to be able to attribute any of the latter to climate change, which is already discussed in the discussion.

3. From the point of view of the structure, the paper needs to be homogeneised. The paragraphs are short and not always contain what the title says. Some attributes, available for subsection of the study area or sub-periods, should be eliminated because they are useless if not available in a homogeneous way (see table 2: "the compensation paid by the CCS to the municipalities in the 230 Spanish Pyrenees for floods that took place between 1996 and 2015, adjusted to 2015" for example).

All paragraphs have been reviewed for length, content, and title. It is true that information on compensation due to floods has only been obtained for Spanish municipalities, and it only exist since 1996, while the study began in 1981, but we believe that this information, that we have obtained from the raw data of the CCS, is useful for the discussion of some results. That is why, following your comment, it has been decided to eliminate the CCS maps and use that information only for discussion.

4. Introduction should be enlarged and improved, mainly by quoting more recent papers published in the latest years of this century. Lines from 41 to 53 describe the study area. Why this part is included in the introduction instead of be in the STUDY AREA section? Figure 1: the size is large with respect to the information contained; a European map must be included to allow the reader to understand where the study area is.

The introduction has been modified following your suggestion. More references have been added and the common thread has been more clearly defined. The description of the study area that appeared between lines 41 to 53 has been moved to the next section and has been integrated into it. Figure 1 has been modified: the top has been cropped, the main rivers and a smaller map showing the location of the Pyrenees have been added.

Below we attach the new Introduction and the new Figure 1 (section 2):

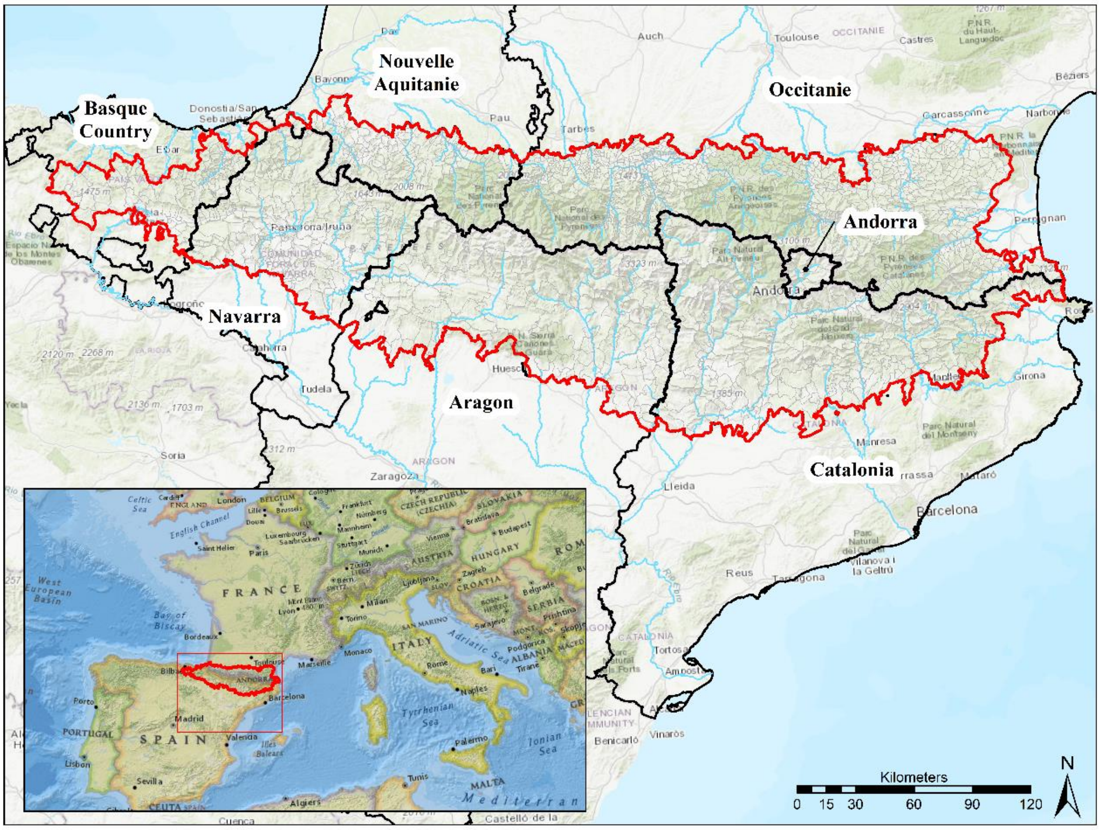

Figure 1: Map of the Pyrenean municipalities located within the area defined as the Pyrenees by the OPCC. The frontiers and names of the Pyrenean regions are also included.

New **Introduction**

It is well known that floods in the Mediterranean area are usually flash floods (Gaume et al., 2009; Braud et al., 2014; Llasat et al., 2016), associated with very heavy rains with a short duration. . In general, they cause local damage in coastal populations or mountainous regions, which can sometimes be very serious. Other times they can affect large regions, as happened with the Gard floods (France) in 2002 (Braud et al., 2010). Most of these episodes do not appear in the best-known flood databases such as EM-DAT (https://www.emdat.be/) or Munich Re's NatCatSERVICE (https://www.munichre.com/en/solutions/for-industry-clients/natcatservice.html), because these databases are often based on indirect information (i.e. from the insurers that Munich Reinsurance reinsures) so many events are not included, either because the insurers are not aware of the events, or because they are not considered to have had sufficient impact (Llasat et al., 2013a; Wirtz et al., 2014). For example, there are very few such episodes that have affected the Pyrenees Mountain region on these databases. More systematic and precise studies are therefore necessary, but the high workload required to elaborate these studies means that they are only available for few regions. This is the case of INUNGAMA (Llasat et al., 2014) that includes all the flood events that have affected Catalonia (NE Spain) between 1981 and 2020 (partial information available in the Flood Observatory of Catalonia, https://experience.arcgis.com/experience/484172e12fae4cbb934441203ee04e36/), andFLOODHYMEX (Llasat et al., 2013b), which currently includes all the catastrophic flood episodes (following the criteria of "catastrophic" introduced in Barriendos et al., 2003) that have affected Catalonia, Valencian Community and the Balearic Islands, in Spain, the former Languedoc-Roussillon region, Midi-Pyrénées and PACA (Provence-Alpes-Côte d'Azur) in France, Calabria, in Italy, and all Greece (available at https://mistrals.sedoo.fr/catalogue/)

On the other hand, concern about the impact of climate change in mountainous regions, including natural hazards, has grown significantly in recent decades. Proof of this is the increase in publications on this topic (i.e. Beniston, 2003; Beniston and Stoffel, 2014; Zimmermann and Keiler, 2015; Steiger et al., 2022) including a cross-chapter devoted to Mountains in the Sixth Assessment Report of IPCC (2022). There are, however, few studies that address mountain massifs in their entirety from a climatic or meteorological perspective. This is the case of the Pyrenees, a cross-border mountainous region between Spain, France and Andorra. ,. To facilitate the international management of a massif distributed between three countries, the Pyrenees Working Community (CTP) was created, which in turn founded the Pyrenean Climate Change Observatory (OPCC, https://www. opcc-ctp.org/en) that promotes the observation and researchon climate change from a multidisciplinary approach. Given that the Pyrenees are key in the generation of water resources in the surrounding regions, where more than 20 million people live, as well as in the production of hydroelectric energy, the OPCC promoted the PIRAGUA project financed by the European call for projects POCTEFA (https://www.opcc-ctp.org/en/piragua) and whose results are available to the public in the OPCC Geoportal (https://www.opcc-ctp.org/en/geoportal) and the publications of Beguería et al. (2023a, 2023b) Among these results, noteworthy are those obtained from trend analysis. Clavera-Gispert et al. (2023) show that in autumn there is a predominance of significant negative trends throughout the mountain range, mainly in September, for low (P10) average (P50) and high flows (P90), for the period 1980-2013. A similar predominance is observed in summer, while only a relevant significant positive trend is observed in the western part (Basque Country, Spain), in the month of March. The decrease in flow throughout the mountain range is more clearly manifested when the period is reduced to 1990-2013. This negative trend becomes more pronounced, even on an annual scale, when analyzing projections of annual precipitation for the middle and end of the century, especially in the western part of the Pyrenees, while in the eastern part, especially in Catalonia (Spain), an increase is observed, which will also be reflected in the average annual flows (Beguería et al., 2023a). CLIMPY, another project from OPCC, concluded that the projections for the next seventy years do not showed a significant trend in the heavy precipitation index (CP95) at the mountain range scale; only a certain decrease could be detected in the south-eastern slope (Catalonia, Spain) and a certain increase in the northern and western parts (French basins, and Navarre and the Basque Country in Spain) (Amblar-Rancés et al., 2020). In this context arises the question about extremes, and specifically, about floods.part. One of the objectives of PIRAGUA was the analysis of floods in the entire Pyrenean region, where flash floods, can have a great direct impact on both the fixed and floating population, as well as on water services and energy resources. Some examples are the catastrophe at Camping las Nieves, in Biescas (Aragón, Spain), on August 7, 1996, in which 87 people drowned (García-Ruiz et al., 1996); the June 2013 floods with catastrophic damages in Spain and France (https://hepex.org.au/flash-floods-in-the-french-western-and-central-pyrenees-17-19-june-2013/); or the floods produced on 7 November 1982 (Trapero et al., 2013) that affected the three Pyrenean countries. The recent death of two people who were canyoning in the Pyrenees of Aragón (Spain) on September 2, 2023, when a flash flood event occurred is another example of this type of event that most people are unaware of. .However, until now there is no database or flood catalogue that specifically covers the Pyrenean regions, and even less so, the Pyrenees massif as a whole. For this reason, in the same way that the final objective of FLOODHYMEX (Llasat et al., 2013) was to cover the entire Mediterranean region, it was decided to create a similar database for the Pyrenees, but that included all types of flood episodes. The aim of this article is to present the first systematic database of flood episodes covering the entire Pyrenees massif, for the period 1981-2015, analyze the trends in light of the most recent articles (Clavera-Gispert et al., 2023), and characterize the weather types favourable to these flood events. This database is available at http://hdl.handle.net/10261/270351 (Llasat et al., 2022). Following the introduction of the study area, the structure of the base, the criteria followed for its construction, and the sources of information used are shown. The spatial and temporal distribution of flood episodes, both in the massif and the administrative regions, as well as the weather types, are then analysed. The paper ends with conclusions and discussion, where some adaptation measures are also commented.

5. A table clearly reporting the main physical characteristics of each study region (and the abbreviation used, possibly being the same throughout the paper…) and the information sources must absolutely be included. As is, this section is very verbose and not understandable, and it is not clear what are the regions,

where they are and what country they belong. The sentence “L 105 In some specific cases, precipitation maps were created from rainfall reanalyses provided by SAFRAN (Quintana et al., 2016), which allowed us to detect some municipalities that suffered flood damage where there was no other record” is unclear. It is the methodology used for some specific region? What region? This must be included in the abovementioned table.

Following your proposal, a table has been introduced in section 2.1 that includes for each region or autonomous community: the country, the number of municipalities that are part of the Pyrenees, the total population of those municipalities, the area they cover, the average GPD of the community, and the sources of information consulted. The phrase relating to SAFRAN (Quintana-Seguí et al., 2016) has been modified to clarify that it has only been used in the case of Navarra and Aragón. Below, we include the new table and the revised paragraph:

2.2 Sources of information and identification of flood events

Table 1 shows the main physical and socioeconomic characteristics of the study area as well as the sources of information used to identify all the flood events that have affected de Pyrenean Region. FLOODHYMEX (Llasat et al, 2013) was used to recover the catastrophic events that have affected the Pyrenees in Catalonia and the part of Occitanie corresponding to the Languedoc-Roussillon. For the Spanish part of the Pyrenees, the National Catalogue of Historical Floods (Catálogo Nacional de Inundaciones Históricas - CNIH) and the information from the Spanish Insurance Compensation Consortium (CCS, 2021) were also used. The CNIH catalogue was published by the General Directorate of Civil Protection in Spain and contains the most important flood events (DGPC, 2022). It is made up of reports made for the different river demarcations into which Spain is divided, observing some heterogeneities, such as the fact that the same event can be in two reports associated with different dates, which requires careful contrast with other sources. The CCS provided for the period 1996-2015 the compensation paid to municipalities in the Pyrenees, organized by postal code and date of the “claim”. which may be different from the date of the flood. In order to resolve this, the postcode data was transformed to a municipality data (a municipality may have more than one postcode) and the damage caused by a flood event was considered to be the sum of the compensations due to floods between the initial day of the event and the final day, with an additional 7 days, as in Cortès et al. (2019). Data from CCS has been also useful to identify some minor flood events that haven’t been found in the other sources of information. Finally, in the case of Catalonia, Aragón and Navarra, the information was completed based on news from the La Vanguardia, El Heraldo de Aragón and Diario de Navarra, newspapers, respectively. La Vanguardia had already been systematically consulted, day by day, for the construction of the INUNGAMA database (Llasat et al, 2014), part of which was included in FLOODHYMEX (Llasat et al., 2013) and PIRAGUA_flood. Given that day-to-day consultation of newspapers is extremely slow, in the case of Aragon and Navarra only the cases identified from the rest of the sources cited above were consulted plus the government press releases and the days of rain that exceeded 40 mm (threshold fixed following the criteria of Cortès et al., 2019). This information was obtained from the precipitation field provided by the SAFRAN analysis (Quintana-Seguí et al., 2016). In the case of the Basque Country and Andorra, the project partners, through whom we obtained the information, confirmed that it was complete, so it was not necessary to consult the newspapers, since the creators of the respective episode lists had done so.

For Nouvelle Aquitaine (AQ) and Occitanie (OC), the databases of the Central Reinsurance Company (Caisse Centrale de Réassurance – CCR) and the National Observatory of Natural Risks (Observatoire National des Risks Naturels - ONRN) were used to create PIRAGUA_flood. In this case the information was completed in basis to the extreme rainfall records of Météo France. This ensured that all episodes that produced notable damage were included, although we must recognize that it is possible that episodes with little damage have gone unnoticed.

Table 1. Main characteristics of the study area. N.munic.: number of municipalities; Total pop.: total population; GDP: mean Gross Domestic Product for the region for the year indicated in the table ; *: value relative to the part of the region that belongs to the Pyrenees. CNIH: Catálogo Nacional de Inundaciones Históricas (National Catalog of Historical Floods); INE: Instituto Nacional de Estadística (National Institute of Statistics); PERICFN: Plan de Emergencia ante el Riesgo de Inundaciones en la Comunidad Foral de Navarra (Emergency Plan for the Risk of Floods

in the Foral Community of Navarra) (https://gobiernoabierto.navarra.es/es/gobernanza/planes-y-programas-accion-gobierno/plan-emergencia-ante-riesgo-inundaciones-comunidad); EPRI: Evaluación Preliminar del Riesgo de Inundación (Preliminary Flood Risk Assessment of the 2nd Cycle of the Eastern Cantabrian Hydrographic Area); CCR: Caisse Centrale de Réassurance (Central Reinsurance Company) (https://catastrophes-naturelles.ccr.fr/); ONRN: Observatoire National des Risques Naturels (National Observatory of Natural Risks) (https://www.georisques.gouv.fr/articles-risques/onrn/acceder-aux-indicateurs-sinistralite#summary-target-1); INSEE: Institut national de la statistique et des études économiques (National Institute of Statistics and Economic Studies) (https://www.insee.fr); CENMA-IEA : Centre d'Estudis de la Neu i de la Muntanya d'Andorra-Institut d'Estudis Andorrans (Andorra Centre of Snow and Mountain Studies-Andorra Studies Institute). GDP data have been obtained from https://Datosmacro.Expansion.Com/Pib/Espana-Comunidades-Autonomas (Spanish regions), https://fr.statista.com/statistiques/479490/pib-par-habitant-selon-regions-france/ (French regions), https://datosmacro.expansion.com/pib/andorra (Andorra).

Region	**Country**	**N.Munic.***	**Area**(km^2)*	**Total pop.***	**GPD**(M€)	**Information sources**
Catalonia (CAT)	Spain	213	12,027.38	255,804	255,154 (2022)	INUNGAMA (Llasat et al, 2014); FLOODHYMEX (Llasat et al, 2013); CNIH (DGPC, 2022); CCS, 2021; La Vanguardia newspaper; INE.
Aragon (AR)	Spain	122	10,594.59	60,624	41,763 (2022)	CNIH (DGPC, 2022); CCS, 2021; El Heraldo de Aragón newspaper; INE.
Navarra (NA)	Spain	186	6,418.75	462,932	22,595 (2022)	CNIH (DGPC, 2022); CCS, 2021; PERICFN; Diario de Navarra newspaper; press releases from the Government of Navarre; SAFRAN (Quintana-Seguí et al., 2016); INE.
Basque Country (PV)	Spain	87	2,585.55	222,533	79,350 (2022)	CNIH (DGPC, 2022); CCS, 2021; EPRI (CHC and URA, 2018); INE.
Nouvelle Aquitaine (AQ)	France	162	3,697.2	104,568	189,300 (2021)	FLOODHYMEX (Llasat et al, 2013); CCR; Météo France; ONRN; INSEE.
Occitanie (OC)	France	1025	14,711.01	409,040	181,300 (2021)	FLOODHYMEX (Llasat et al, 2013); CCR; Météo France; ONRN; INSEE.
Andorra (AND)	Andorra	7	468	815,888	3,210 (2022)	CENMA-IEA; Database of the Ministeri d'Ordenament Territorial (Ministry of the Territorial Planning) of the Government of Andorra.

6. In Database structure and methodology, it is necessary to put a figure to show the structure of the database because in this way is not understandable. I don't understand what is the meaning of the two tables described and what is the relation between them. How these tables are linked?

Following your proposal, a figure has been included in section 3 that shows the structure of the database and the relationship between the two tables. Both tables are linked by the event code. The new figure and text are the following:

The database was built in ACCESS but to facilitate its use by any person interested in it, the public version is in EXCEL. It is made up of two tables: a) Events; b) Affected municipalities that are linked throughout the event code (Fig. 2). Tables 2 and 3 show the information and criteria used to create each one of these tables, that follows the example of FLOODHYMEX and INUNGAMA databases.

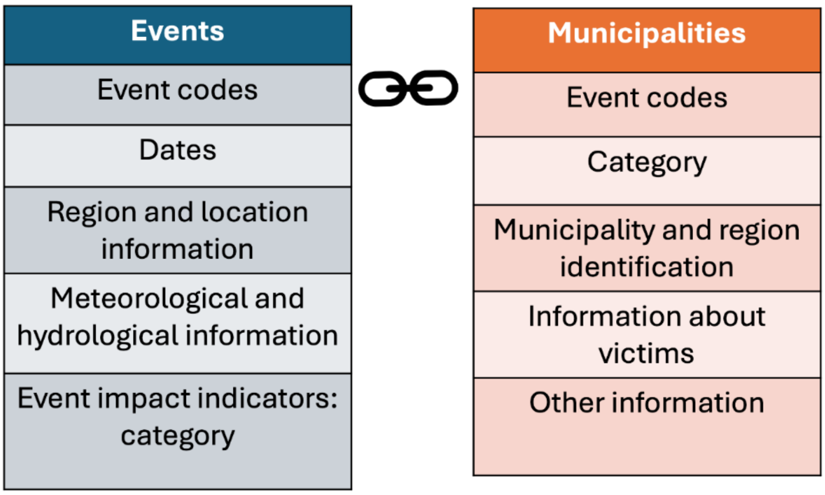

Figure 2. Structure of the PIRAGUA_flood database

In response to your last comment, two tables have been included in this section that summarize Annex 1, which in the modified version will no longer appear. Tables 2 and 3 are included in our answer to your question 10.

7. Line 111: there is a typo. Table 1: put a legend to explain the meaning of the colors

Line 111 has been corrected. Old Table 1 has been deleted and replaced by Figure 3. The new paragraph and figure are showed as follows:

The category of flood events is based on the level of impacts and is divided into categories: 0 (ordinary), 1 (extraordinary), 2 (catastrophic), and 3 (major catastrophic), according to Figure 3, inspired by the criteria presented in previous publications (Barriendos et al., 2003; Llasat et al., 2013, 2016; Barrera-Escoda and Llasat, 2015). However, in these publications, the distinction between categories was purely subjective. In order to facilitate its reproduction by other authors, a table has been designed to help decide in which category an event can be classified. Firstly, the "Damage indicators" have been selected based on literature (Petrucci, 2013; Boudou et al., 2016; Vinet et al., 2016). For each one of the indicators, the "Damage level" has been analyzed, where level 1 refers to possible minor damage (small floods in basements, breakdowns in traffic lights, etc.), level 2 refers to medium damages (it includes floods inside buildings and on communication routes which can cause traffic interruptions, partial damage to infrastructure, etc.), and level 3 refers to major impacts in the indicator (partial or total destruction of buildings, roads, bridges, long lasting supply cuts, etc.). To classify flood episodes into categories, the level of damage in each of the seven indicators is taken into account, as shown in Figure 3. Fatalities are not included in Figure 3 as they can occur in any flood event category, although they are more likely to occur in catastrophic floods. The same applies to vehicles, as they can be swept away if they are parked on a creek where there is normally little water flow, without the river breaking its banks. This is why additional information has been included in the database, with the code of "0.5" if the episode swept away cars and "5" if there were fatalities. Since the category of the episode may be different for each affected Pyrenees municipality, the highest occurring level determines the category of the episode.

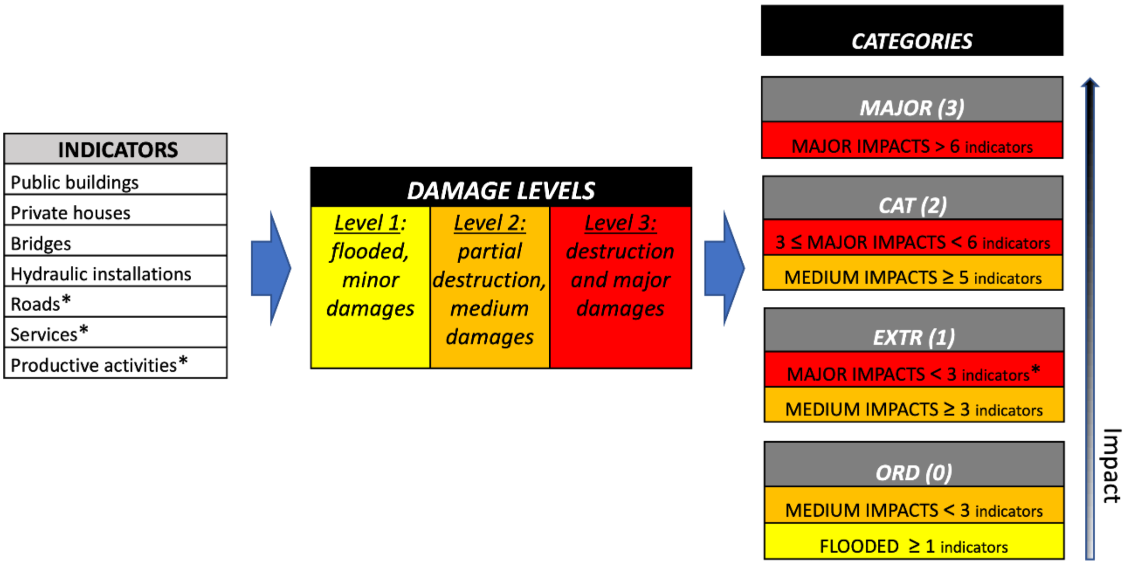

Figure 3: Criteria for categorizing flood events based on impacts. ORD (0): Ordinary flood event; EXTR (1): extraordinary flood event; CAT (2): catastrophic flood event; MAJOR (3): major catastrophic event. The level of damage is estimated from the direct impacts experienced, and a color scale is used (level 1: yellow; level 2: orange; level 3: red).

8. Figure 5-6-7-8: it is unclear where we are in the study region. It is almost useless to put the name of some municipality in very big characters, because readers living outside Europe are not required to know those municipalities. Instead, as in this scientific sector is a common practice, a small framework of study area and sub section must be used (the same size for all the figures).

Figures 2 and 4 have been modified using the same scale for both of them, as follows:

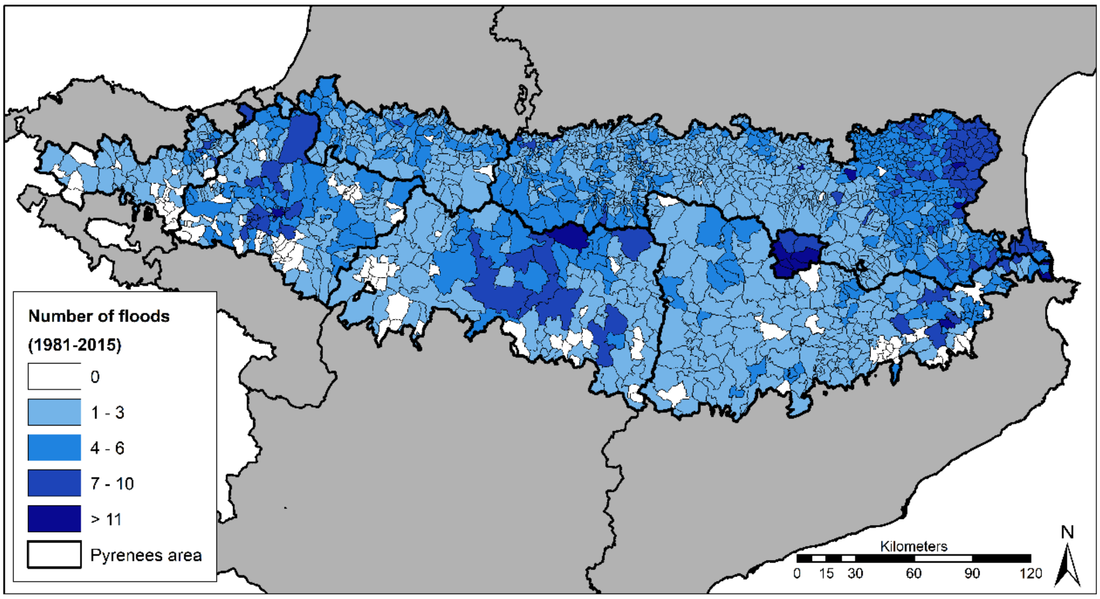

Figure 5 (old Figure 2): Number of total flood events that affected each municipality in the Pyrenees between 1981 and 2015.

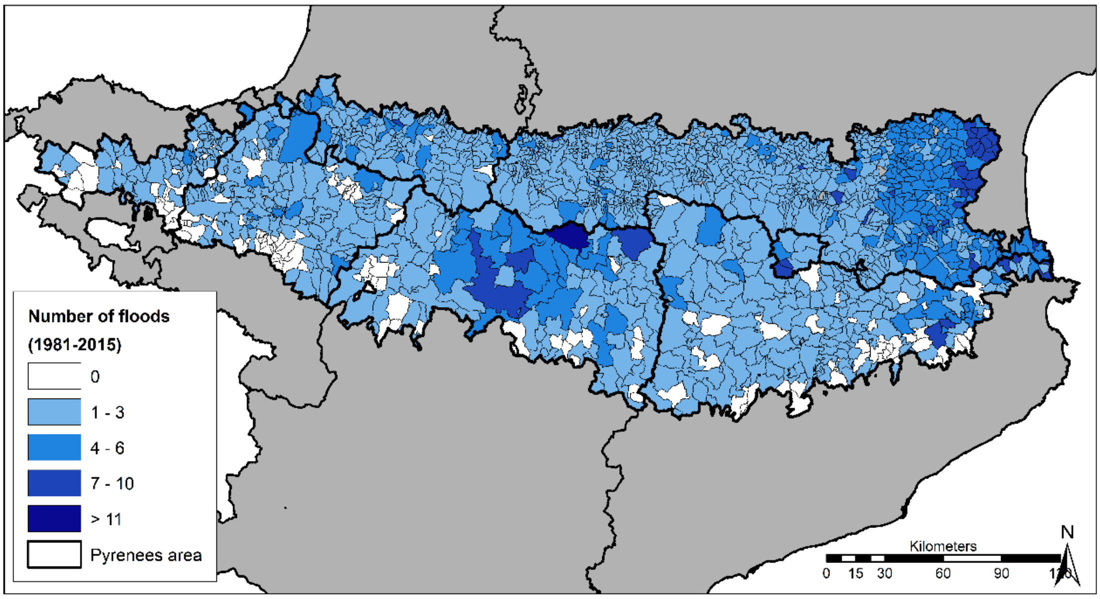

Figure 7 (old Figure 4): Number of notable flood events (catastrophic and extraordinary floods) that affected each municipality in the Pyrenees.

The revised text corresponding to these figures is:

Figure 5 shows that the highest concentration of flood episodes occurs in Andorran municipalities and in the easternmost area of Occitanie and Catalonia. Some municipalities in Aragón and Navarra also stand out, while in the Basque Country and Nouvelle Aquitanie, no municipality have recorded more than 7 episodes of flooding. The region with the highest total number of flood events was Catalonia (66), followed by Andorra (46), while the lowest number was recorded in the Basque Country (16). Andorra is the region that records the highest percentage of ordinary floods (67.4%) although the absolute maximum corresponds to Catalonia (Fig.6). This regional difference may be related to both the orography and the meteorological disturbances causing intense rains, which will be discussed later. The highest number of catastrophic flood events was recorded in Nouvelle Aquitaine, followed by Occitanie and Aragón.

We cannot forget, however, that it is possible that some ordinary floods in France have gone unnoticed. This is why figure 7 has been constructed. It shows the distribution by municipality of flood events with notable damage (that is, they were extraordinary or catastrophic). The distribution hardly changes with respect to figure 4, and only the maxima of some municipalities are smoothed out. Of the 181 flood events, 52% produced notable damages in one or more of the Pyrenean regions. It is observed that notable flooding events are concentrated above all in the municipalities of the Pyrenees closest to the Mediterranean, both on the Spanish and French sides. The central part of the Spanish Pyrenees also stands out, located at the foot of the highest mountains.

Taking into account your consideration that it is unnecessary to indicate the mentioned municipalities on the maps, as well as the homogenization of the information for all regions, which forces the elimination of the maps of the estimated impacts from the CCS data, we believe It is not necessary to put individual maps of the total number of floods, since that information appears in the old figure 2 (current figure 5).

9. Table 3. I don't understand why in this table the authors used the nations. I suggest to maintain both the names of the countries and the regions, in two lines of the table. The same for table 4.

Old tables 3 and 4 showed the transnational flood events, and for this reason we have used the name of the countries. In these tables we don't show the cross-border events between regions. Considering your comment, we have completely modified both tables. Old Table 3 has been replaced by the following figure 9 that illustrates the monthly distribution of cross-border flood events.

Figure 9. Monthly total number of flood events recorded in the Pyrenean Region (1981-2015), for each country (SP: Spain; FR: France; AND: Andorra) and for cross-border events.

Your proposal about searching not only for transnational events but also for transregional events seemed very accurate to us and we have constructed the following table:

Table 6. Number of events that have affected each Pyrenean region and number of events that have affected each pair of regions indicated by the intersection by them.

	CAT	AR	NA	PV	AND	OC	AQ
CAT	66						
AR	10	37					
NA	0	1	24				
PV	1	1	3	16			
AND	7	8	0	0	46		
OC	17	8	2	2	2	36	
AQ	3	4	5	4	1	10	17

10. Appendix A: must be completely rearranged in a schematic way, in form of a table, because as is it is useless

Following your proposal, Appendix 1 has been eliminated and the information that it contained has been synthesized in two tables that have been introduced in section 3. Both tables are the following:

Table 2. Information and criteria used to fill out the EVENTS table.

Event codes	**Integrated Event Code**: numerical code used to identify the event that have affected one or more regions. Indicates the first and last day on which the event has been registered in the entire Pyrenean region.
	Event: Numeric field composed of the start and end dates of the event in the specific region
Dates	**Start date**: Indicates the beginning of the episode in the specific region.
	End date: Indicates the end of the episode in the specific region. Criteria: -The event starts when the rain starts in the region. -The event ends when the flood ends. -A subsequent episode is considered a new episode when there is more than one day (at least) without any of the previous conditions occurring.
Location information	**Region**: Indicates the administrative region affected by the event: Aragon (AR), Catalonia (CAT), Navarre (NA), Basque Country (PV); Occitanie (OC), Nouvelle-Aquitaine (AQ), Andorra (AND)
	Location 1: List of affected counties in the specific region
	Location 2: List of affected municipalities in the specific region
	Number of municipalities affected: number of municipalities that suffered damages in the specific region
	Affected area (Km^2): Sum of the total area of the affected municipalities, in Km^2
Meteorological and hydrological information	**Ptotal (Loc), Pmax (24 h) (Loc) o P (h) (Loc) (mm)**: It indicates the maximum cumulated precipitation in all the event or/and the maximum precipitation in 24h in mm or/and the maximum rainfall intensity in mm/h and its duration. In the three cases the station where the value was recorded is indicated.
	Other meteorological data: Optional field to add more hydrometeorological information.
	Other weather phenomena: Other adverse natural phenomena occurred in addition to floods: landslide, debris flow, hail, snow, windstorm, tornado, snow melting, lightning.
	Affected drainage basins: List of affected river basins
	Maximum flow (m^3/s): Maximum instantaneous flow recorded indicating the river, gauging station and date, in addition to the average annual flow. If information is available for more than one river, it is included.
Event impact indicators	**Category**: The category of the flood event in the region according to the criteria described in section 3.1. There is a column for each category and supplementary categories

Table 3. Information and criteria used to fill out the MUNICIPALITIES table.

Event codes	**Integrated Event Code**: numerical code used to identify the event that have affected one or more regions. Indicates the first and last day on which the event has been registered in the entire Pyrenean region.
	Event: Numeric field composed of the start and end dates of the event in the specific region. The same code that identifies the event in the "Events" table must be used.
Category	**Event category**: The category of the flood event in the region according to the criteria described in section 3.1. There is a column for each category..
Municipality and region identification	**MunicipalityID**: Code (NATCODE, INSEE or equivalent) of the municipality affected by the floods. Each row is for a municipality, which means an event can have more than one row.
	Location name: Name of the municipality.
	Region: region to which the municipality belongs
	Deceased: Total number of fatalities in the municipality (if any).

Information about victims	**Gender and age of victims**: When information is available, the gender and age of each victim is indicated.
	Causes: A brief description of the causes of death.
Other information	**Other information**: Supplementary information that is not covered in the other fields.

11. The list with the new references cited here is found after the response to the second reviewer

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Answers to Review 2

> This paper presents a detailed inventory of floods having caused significant damages and/or disruptions in the Pyrenean mountains for the 1981 – 2015 period, and proposes some analyses in terms of frequency, geographical distribution, temporal distribution, trends, and weather types related to these flood events. The presented database is rich (181 events, coverage of the whole Pyrenean region, information combining intensity of damages, victims, and compensation costs) and brings interesting information about the occurrence of floods in the considered region.
>
> However, I think this paper should be significantly improved on the following aspects (see also my detailed comments hereafter):

Dear reviewer,

Above all, we want to express our acknowledgement for the time spent reviewing this paper. We have carefully considered all your comments, as well as those from the other reviewer, and have implemented substantial revisions to the paper. We are confident that these changes have significantly enhanced the quality of our work. In order to facilitate you the revision we have chosen to introduce here those paragraphs, figures and tables that have been significantly modified or that are new.

We would like to thank you again for your helpful feedback and availability to review this paper.

Maria Carmen Llasat on behalf of all the authors

1. Some possible limits affecting the comprehensiveness of the inventory should be better stated and discussed. Particularly, obtaining a very low number of ordinary events in some specific regions is certainly caused by some limits in the inventory, provided that the sources of information involved are different for each region. For this reason, I think that most of the proposed analyses should rather focus on extraordinary and catastrophic events, than on the total number of events

Indeed, it is not possible to have information with the same detail for all regions. To make this clearer, in the new version we have modified section 2.2, which is now as follows. However, we cannot ignore the information obtained for all regions also considering the ordinary episodes, since they are not easy to find. That is why the category of notable events has been introduced, which includes catastrophic and extraordinary events.

Both in response to your comments and those of the other reviewer, the section dedicated to the description of the sources of information has been considerably improved, the partial figures of the regions have been eliminated and two new figures have been constructed that show the flooding throughout the Pyrenees massif, both total and notable, in which the scales are the same and where the regional limits have been marked. A table has also been introduced in section 2.1 that includes for each region or autonomous community: the country, the number of municipalities that are part of the Pyrenees, the total population of those municipalities, the area they cover, the average GPD of the community, and the sources of information consulted.

Below is the new text of the section, as well as the table and both figures:

2.2 Sources of information and identification of flood events

Table 1 shows the main physical and socioeconomic characteristics of the study area as well as the sources of information used to identify all the flood events that have affected de Pyrenean Region. FLOODHYMEX (Llasat et al, 2013) was used to recover the catastrophic events that have affected the Pyrenees in Catalonia and the part of Occitanie corresponding to the Languedoc-Roussillon. For the Spanish part of the Pyrenees, the National Catalogue of Historical Floods (Catálogo Nacional de Inundaciones Históricas - CNIH) and the information from the Spanish Insurance Compensation Consortium (CCS, 2021) were also used. The CNIH catalogue was published by the General Directorate of Civil Protection in Spain and contains the most important flood events (DGPC, 2022). It is made up of reports made for the different river demarcations into which Spain is divided, observing some heterogeneities, such as the fact that the same event can be in two reports associated with different dates, which requires careful contrast with other sources. The CCS provided for the period 1996-2015 the compensation paid to municipalities in the Pyrenees, organized by postal code and date of the "claim" which may be different from the date of the flood. In order to resolve this, the postcode data was transformed to a municipality data (a municipality may have more than one postcode) and the damage caused by a flood event was considered to be the sum of the compensations due to floods between the initial day of the event and the final day, with an additional 7 days, as in Cortès et al. (2019). Data from CCS has been also useful to identify some minor flood events that haven't been found in the other sources of information. Finally, in the case of Catalonia, Aragón and Navarra, the information was completed based on news from La Vanguardia, El Heraldo de Aragón and Diario de Navarra, newspapers, respectively. La Vanguardia had already been systematically consulted, day by day, for the construction of the INUNGAMA database (Llasat et al, 2014), part of which was included in FLOODHYMEX (Llasat et al., 2013) and PIRAGUA_flood (Llasat et al., 2022). Given that day-to-day consultation of newspapers is extremely slow, in the case of Aragon and Navarra only the cases identified from the rest of the sources cited above were consulted plus the government press releases and the days of rain that exceeded 40 mm (threshold fixed following the criteria of Cortès et al., 2019). This information was obtained from the precipitation field provided by the SAFRAN analysis (Quintana-Seguí et al., 2016). In the case of the Basque Country and Andorra, the project partners, through whom we obtained the information, confirmed that it was complete, so it was not necessary to consult the newspapers, since the creators of the respective episode lists had done so.

For Nouvelle Aquitaine (AQ) and Occitanie (OC), the databases of the Central Reinsurance Company (Caisse Centrale de Réassurance – CCR) and the National Observatory of Natural Risks (Observatoire National des Risks Naturels - ONRN) were used to create PIRAGUA_flood. In this case the information was completed in basis to the extreme rainfall records of Météo France. This ensured that all episodes that produced notable damage were included, although we must recognize that it is possible that episodes with little damage have gone unnoticed.

Table 1. Main characteristics of the study area. N.munic.: number of municipalities; Total pop.: total population; GDP: mean Gross Domestic Product for the region for the year indicated in the table ; *: value relative to the part of the region that belongs to the Pyrenees. CNIH: Catálogo Nacional de Inundaciones Históricas (National Catalog of Historical Floods); INE: Instituto Nacional de Estadística (National Institute of Statistics); PERICFN: Plan de Emergencia ante el Riesgo de Inundaciones en la Comunidad Foral de Navarra (Emergency Plan for the Risk of Floods in the Foral Community of Navarra) (https://gobiernoabierto.navarra.es/es/gobernanza/planes-y-programas-accion-gobierno/plan-emergencia-ante-riesgo-inundaciones-comunidad); EPRI: Evaluación Preliminar del Riesgo de Inundación (Preliminary Flood Risk Assessment of the 2nd Cycle of the Eastern Cantabrian Hydrographic Area); CCR: Caisse Centrale de Réassurance (Central Reinsurance Company) (https://catastrophes-naturelles.ccr.fr/); ONRN: Observatoire National des Risques Naturels (National Observatory of Natural Risks) (https://www.georisques.gouv.fr/articles-risques/onrn/acceder-aux-indicateurs-sinistralite#summary-target-1); INSEE: Institut national de la statistique et des études économiques (National Institute of Statistics and Economic Studies) (https://www.insee.fr); CENMA-IEA : Centre d'Estudis de la Neu i de la Muntanya d'Andorra-Institut d'Estudis Andorrans (Andorra Centre of Snow and Mountain Studies-Andorra Studies Institute). GDP data have been obtained from https://Datosmacro.Expansion.Com/Pib/Espana-Comunidades-Autonomas (Spanish regions), https://fr.statista.com/statistiques/479490/pib-par-habitant-selon-regions-france/ (French regions), https://datosmacro.expansion.com/pib/andorra (Andorra).

Region	**Country**	**N.Munic.***	**Area**(km^2)*	**Total pop.***	**GPD**(M€)	**Information sources**

Catalonia (CAT)	Spain	213	12,027.38	255,804	255,154 (2022)	INUNGAMA (Llasat et al, 2014); FLOODHYMEX (Llasat et al, 2013); CNIH (DGPC, 2022); CCS, 2021; La Vanguardia newspaper; INE.
Aragon (AR)	Spain	122	10,594.59	60,624	41,763 (2022)	CNIH (DGPC, 2022); CCS, 2021; El Heraldo de Aragón newspaper; INE.
Navarra (NA)	Spain	186	6,418.75	462,932	22,595 (2022)	CNIH (DGPC, 2022); CCS, 2021; PERICFN; Diario de Navarra newspaper; press releases from the Government of Navarre; SAFRAN (Quintana-Seguí et al., 2016); INE.
Basque Country (PV)	Spain	87	2,585.55	222,533	79,350 (2022)	CNIH (DGPC, 2022); CCS, 2021; EPRI (CHC and URA, 2018); INE.
Nouvelle Aquitaine (AQ)	France	162	3,697.2	104,568	189,300 (2021)	FLOODHYMEX (Llasat et al, 2013); CCR; Météo France; ONRN; INSEE.
Occitanie (OC)	France	1025	14,711.01	409,040	181,300 (2021)	FLOODHYMEX (Llasat et al, 2013); CCR; Météo France; ONRN; INSEE.
Andorra (AND)	Andorra	7	468	815,888	3,210 (2022)	CENMA-IEA; Database of the Ministeri d'Ordenament Territorial (Ministry of Territorial Planning) of the Government of Andorra.

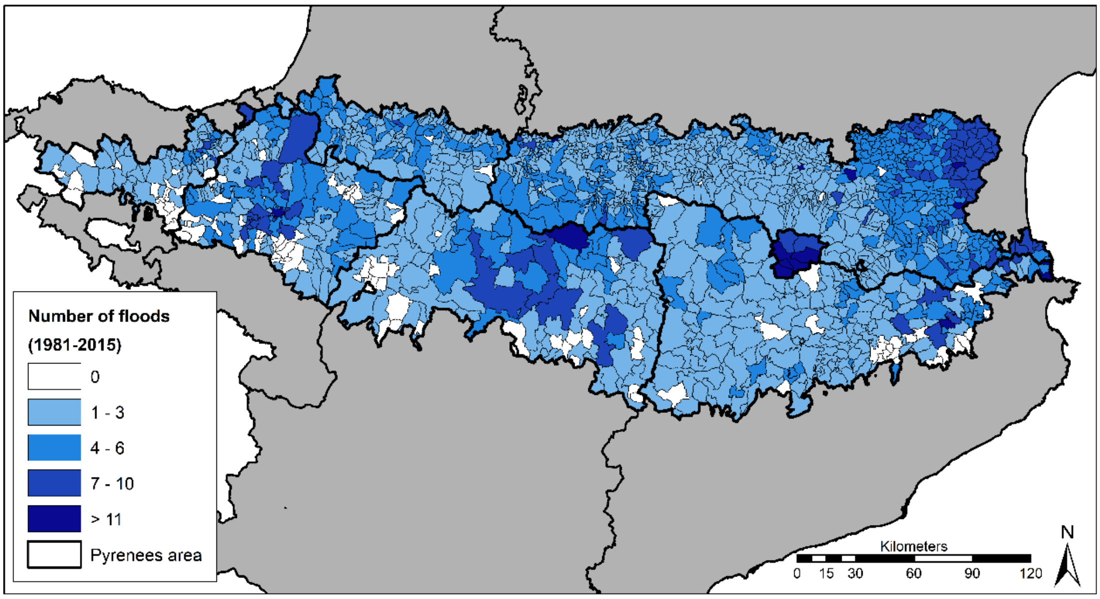

Figure 5 (old Figure 2): Number of total flood events that affected each municipality in the Pyrenees between 1981 and 2015.

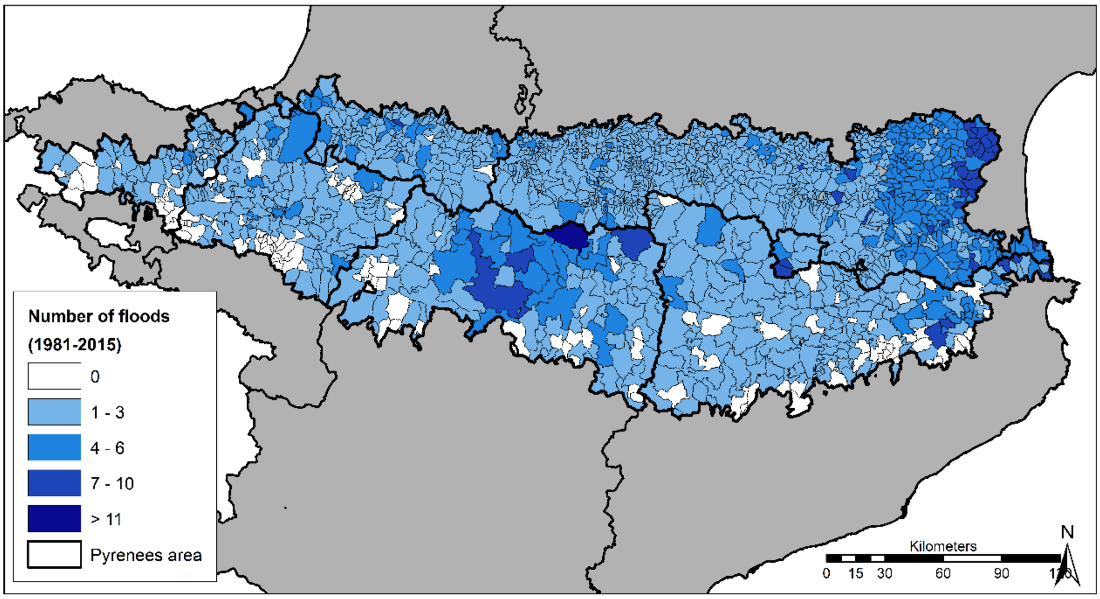

Figure 7 (old Figure 4): Number of notable flood events (catastrophic and extraordinary floods) that affected each municipality in the Pyrenees.

2. Some methodological details would require some additional explanations. This concerns both the procedure used for flood inventory (consultation of newspapers limited to pre-identified dates? How the 0.5 and 5 codes representing cars swept away and victims ca be combined with the 1 to 3 codes representing flood severity?), and the methods used for analysis of trends (definition of the variable used) and weather types (definition of the "daily averaged" fields).

I believe that the new text in section 2.2 and new table 1 included in response to the previous question already includes the answer to the question relative to the flood inventory. As you have seen, the systematic consultation of the press day by day for the entire period 1980-2015 has been done for Catalonia. For the remaining regions it was limited to pre-identified data (CCS, CNIH, government releases, rainfall fields, etc.).

As for categories 0.5 and 5, these are independent of categories 0 to 3. A flood can be ordinary and cause victims, or it can be catastrophic and cause no victims. Previous publications have shown that the severity of the flood cannot be related to mortality. According to Llasat et al. (2014), 69% of catastrophic episodes had victims. We have modified the text and included a new figure to explain how we have proceeded to do the categorization. Below are the figure and corrected text:

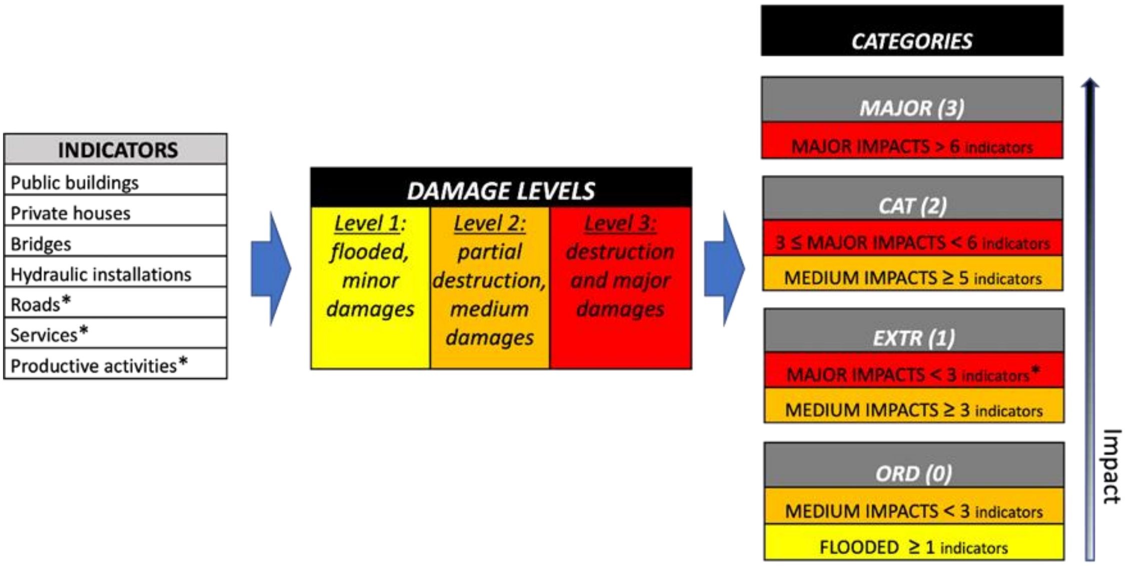

Figure 3: Criteria for categorizing flood events based on impacts. ORD (0): Ordinary flood event; EXTR (1): extraordinary flood event; CAT (2): catastrophic flood event; MAJOR (3): major catastrophic event. The level of damage is estimated from the direct impacts experienced, and a color scale is used (level 1: yellow; level 2: orange; level 3: red).

The category of flood events is based on the level of impacts and is divided into categories: 0 (ordinary), 1 (extraordinary), 2 (catastrophic), and 3 (major catastrophic), according to Figure 3, inspired by the criteria presented in previous publications (Barriendos et al., 2003; Llasat et al., 2013, 2016; Barrera-Escoda and Llasat, 2015). However, in these publications, the distinction between categories was purely subjective. In order to facilitate its reproduction by other authors, a table has been designed to help decide in which category an event can be classified. Firstly, the "Damage indicators" have been selected based on literature (Petrucci, 2013; Boudou et al., 2016; Vinet et al., 2016). For each one of the indicators, the "Damage level" has been analyzed, where level 1 refers to possible minor damage (small floods in basements, breakdowns in traffic lights, etc.), level 2 refers to medium damages (it includes floods inside buildings and on communication routes which can cause traffic interruptions, partial damage to infrastructure, etc.), and level 3 refers to major impacts in the indicator (partial or total destruction of buildings, roads, bridges, long lasting supply cuts, etc.). To classify flood episodes into categories, the level of damage in each of the seven indicators is taken into account, as shown in Figure 3. Fatalities are not included in Figure 3 as they can occur in any flood event category, although they are more likely to occur in catastrophic floods. The same applies to vehicles, as they can be swept away if they are parked on a creek where there is normally little water flow, without the river breaking its banks. This is why additional information has been included in the database, with the code of "0.5" if the episode swept away cars and "5" if there were fatalities. Since the category of the episode may be different for each affected Pyrenees municipality, the highest occurring level determines the category of the episode.

Regarding the methods used for analysis of trends we have expanded as it is showed in our answer to your comment relative to l.139-140, where the revised text is included. The trend analysis has been applied over the number of flood events per year, taking into account the total number and the different categories.

Regarding the weather types procedure, we have added additional figures and explanations. Further details are provided in the specific comments below referring to this issue.

3. Some sections (4.2 and 6) do not bring significant information in my opinion, and could be highly summarized based on a much more limited number of figures, to put the emphasis on other (more informative) sections.

Section 4.2. “Regional flood events distribution” has been considerably reduced, eliminating the figures, and focusing on the spatial distribution and the role that vulnerability and exposure to floods can play in this distribution. The figures of reference are the new figures 5 and 7, and the new text for section 4.2 is:

In the study period (1981-2015) there were 66 episodes in the Catalan Pyrenees in which the number of victims amounted to 21. Three episodes were catastrophic and 26 were extraordinary (Table 4). Figure 4 shows that the highest number of floods took place in the coastal foothills of the Pyrenees (16 episodes in the coastal municipality of Llançà, of which 62% were extraordinary) that confirms the strong role played by the entrance of Mediterranean air masses. In Aragon there were a total of 37 flood events, of which 13.5% were catastrophic. In 4 of them there were flash floods that led to the evacuation or death of several people who were canyoning. The number of victims amounts to 97, 87 of whom died at the Las Nieves campsite (Biescas) in August 1996 (Ayala Carcedo, 2002). Aragon has the county with the highest number of flash floods in the Pyrenees and it is Sobrarbe, where 26 events have taken place in 35 years. These are mainly events associated with thunderstorms in which the orography forces the rise and hinders the advance of convective systems, which can remain stationary in the same place (i.e. the Biescas case). The large number of torrents and dejection cones favors the production of flash floods. Given that these are very attractive mountain areas, it is possible that there are campsites, hikers or high-risk sportsmen and sportswomen, which increases vulnerability and exposure. The Navarre Pyrenees were affected by 24 events (17%, catastrophic) in which there was one victim. In this case, the damage is usually due to urban and peri-urban flooding, affecting its capital, Pamplona (203,418 inhabitants) that is the Pyrenean city with the largest number of recorded events (17). However, the most catastrophic episodes in Navarra have occurred in the Baztan valley, where numerous villages and small industries extend around the river. During the period 1981-2015 only 6 episodes of flooding (25% catastrophic) affected the Basque Pyrenees, with two victims. Most of them were concentrated in the eastern part of the region, near the Baztan valley. Although it is true that the costliest flood event recorded in Spain in that period took place in the Basque Country, in August 1983, the greatest damage occurred around the coastal estuaries, outside the Pyrenean region. Precisely, if the economic costs are taken into account, the CCS paid a total of €33.4 million_{2015} (M_{2015}) in flood compensation in the Catalan Pyrenean Region in the period 1996-2015, with the Val d'Aran being the most compensated region (a recreation and ski area with luxurious urbanizations near the river), mainly due to the June 2013 event that also affected Aragón and the French Pyrenees (Table 7). For the same period, the CCS paid a total of €15.2 M_{2015} in flood compensations in Aragón, mainly due to the flood events of August 1996 (the Biescas case), that also affected Andorra, and the flood event of June 2013. The CCS paid a total of €65.8 M_{2015} in flood compensation in Navarra, of which about €18 M_{2015} went to Pamplona and €5.5 M_{2015} went to Baztan. The CCS paid a total of €28.1 M_{2015} in flood compensation in the Basque Pyrenees, of which the largest amounts went to Tolosa (19.525 inhabitants, the most important city in the region).

A total of 46 flood events were recorded in Andorra in the period 1981-2015, of which only 4.55% were catastrophic. It is a country of 79,824 inhabitants with a very high risk of flooding, especially because the most important towns and villages are surrounding the Valira River in a very narrow valley. The most important heavy rainfall events are usually due to Mediterranean perturbations that also affect Catalonia and/or Aragón (table 7). The maximum number of flood events occurred in the municipality of Andorra la Vella (27), followed by Sant Julià de Lòria (18). In total, 43 episodes of floods affected the French side of the Pyrenees, of which Nouvelle Aquitaine recorded 17 events and Occitanie recorded a total of 36 events, with a percentage of catastrophic episodes of 35.3% and 13.9%, respectively. Ten of these episodes were common to the two regions. In Occitanie, the municipality with the most flood episodes was Montgaillard, with 13, while in Nouvelle Aquitaine the maximum was lower, with 7 events in Mauleon-Licharre. Both populations are located closer to the Atlantic than the Mediterranean, being exposed above all to disturbances from the west and northwest. As a whole, however, the municipalities located further east in Occitanie stand out, where floods are mainly associated with disturbances such as those affecting Catalonia and Andorra. It is noteworthy that all the municipalities in the French Pyrenees have recorded at least one catastrophic flood event, with the maximum recorded in the northeastern part, close to the Mediterranean.

The objective of section 6 was to show that some events were cross-border and that therefore collaboration between the authorities of different countries or regions could improve the management of these types of episodes and early warning. In response to your comment, a paragraph about it has been included in the Discussion part. New paragraph is:

As it has been shown in the paper, many flood episodes are transnational, which calls for cooperation in the prevention and mitigation of flood risk between regions and countries. This is more relevant considering the United Nations call "Erly Warning for All" to ensure that everyone on Earth is protected from hydrometeorological hazard, including flood events through life-saving early warning systems by the end of 2027. Furthermore, in Europe there is a strong collaboration framework, both thanks to the ESA Copernicus observation program, Meteoalarm and within the Euromed Program of Prevention, Preparedness and Response to Natural and Man-made Disasters, in which all European Civil Protection agencies participate. However, it is necessary to land it in the interborder region of the Pyrenees.

On the other hand, old Table 3 has been replaced by the following figure 9 that illustrates the monthly distribution of cross-border flood events.

Figure 9. Monthly total number of flood events recorded in the Pyrenean Region (1981-2015), for each country (SP: Spain; FR: France; AND: Andorra) and for cross-border events.

And a table showing the transregional events have been included:

Table 6. Number of events that have affected each Pyrenean region and number of events that have affected each pair of regions indicated by the intersection by them.

	CAT	AR	NA	PV	AND	OC	AQ
CAT	66						
AR	10	37					
NA	0	1	24				
PV	1	1	3	16			
AND	7	8	0	0	46		
OC	17	8	2	2	2	36	
AQ	3	4	5	4	1	10	17

4. The links between floods and weather types (section 7) are not presented in an optimal manner. I think this section should include additional information to

better illustrate the relative weights of the different weather types causing floods, and the temporal and geographical repartition of these weights.

The authors acknowledge the reviewer's comment. We have addressed this point by adding a figure, as is explained in our answers to specific comments that indicates the number of flood days per weather type and Pyrenean region. This new figure allows to understand the spatial patterns of floods in relation to the different weather types. Additionally, we also improved the previous version of old figure 17, by adding the absolute number of flood days per WT and month. Further details on this are given in the corresponding comment about this issue.

5. Considering this, my opinion is that this paper would require major revisions before publication.

Thank you very much for the suggestions you have made that will considerably improve the article. We agree with you that the article required major changes, which we have already proceeded to make.

Detailed comments :

l.10 "the results of the analysis of the first"

Done

l.13 I suggest to replace "adapting to" with "and adapted to"

Done

l.16 Replace "paid out made" with "paid out"

Done

l.20 Please provide an explanation here for the meaning of «million2015 »

It means that the economic value has been updated to the year 2015, in order to compare it. This clarification has been added to the paper.

l.29 "unnoticed in the databases" Which databases? Do you mean here databases providing inventories of damaging flood events which are detailed in the next sentences, and/or more generally hydrometeorological databases that may also fail to capture heavy rainfall events and floods because of the too coarse density of observation networks. Could you please provide more details?

We agree. The entire introduction has been modified, including this sentence. The new Introduction is:

New **Introduction**

It is well known that floods in the Mediterranean area are usually flash floods (Gaume et al., 2009; Braud et al., 2014; Llasat et al., 2016), associated with very heavy rains with a short duration. . In general, they cause local damage in coastal populations or mountainous regions, which can sometimes be very serious. Other times they can affect large regions, as happened with the Gard floods (France) in 2002 (Braud et al., 2010). Most of these episodes do not appear in the best-known flood databases such as EM-DAT (https://www.emdat.be/) or Munich Re's NatCatSERVICE (https://www.munichre.com/en/solutions/for-industry-clients/natcatservice.html), because these databases are often based on indirect information (i.e. from the insurers that Munich Reinsurance reinsures) so many events are not included, either because the insurers are not aware of the events, or because they are not considered to have had sufficient impact (Llasat et al., 2013a; Wirtz et al., 2014). For example, there are very few such episodes that have affected the Pyrenees Mountain region on these databases. More systematic and precise studies are therefore necessary, but the high workload required to elaborate these studies means that they are only available for few regions. This is the case of INUNGAMA (Llasat et al., 2014) that includes all the flood events that have affected Catalonia (NE Spain) between 1981 and 2020 (partial information available in the Flood Observatory of Catalonia, https://experience.arcgis.com/experience/484172e12fae4cbb934441203ee04e36/), andFLOODHYMEX (Llasat et al., 2013b), which currently includes all the catastrophic flood episodes (following the criteria of "catastrophic" introduced in Barriendos et al., 2003) that have affected Catalonia, Valencian Community and the Balearic Islands, in Spain, the former Languedoc-Roussillon region, Midi-Pyrénées and PACA (Provence-Alpes-Côte d'Azur) in France, Calabria, in Italy, and all Greece (available at https://mistrals.sedoo.fr/catalogue/)

On the other hand, concern about the impact of climate change in mountainous regions, including natural hazards, has grown significantly in recent decades. Proof of this is the increase in publications on this topic (i.e. Beniston, 2003; Beniston and Stoffel, 2014; Zimmermann and Keiler, 2015; Steiger et al., 2022) including a cross-chapter devoted to Mountains in the Sixth Assessment Report of IPCC (2022). There are, however, few studies that address mountain massifs in their entirety from a climatic or meteorological perspective. This is the case of the Pyrenees, a cross-border mountainous region between Spain, France and Andorra. ,. To facilitate the international management of a massif distributed between three countries, the Pyrenees Working Community (CTP) was created, which in turn founded the Pyrenean Climate Change Observatory (OPCC, https://www. opcc-ctp.org/en) that promotes the observation and researchon climate change from a multidisciplinary approach. Given that the Pyrenees are key in the generation of water resources in the surrounding regions, where more than 20 million people live, as well as in the production of hydroelectric energy, the OPCC promoted the PIRAGUA project financed by the European call for projects POCTEFA (https://www.opcc-ctp.org/en/piragua) and whose results are available to the public in the OPCC Geoportal (https://www.opcc-ctp.org/en/geoportal) and the publications of Beguería et al. (2023a, 2023b) Among these results, noteworthy are those obtained from trend analysis. Clavera-Gispert et al. (2023) show that in autumn there is a predominance of significant negative trends throughout the mountain range, mainly in September, for low (P10) average (P50) and high flows (P90), for the period 1980-2013. A similar predominance is observed in summer, while only a relevant significant positive trend is observed in the western part (Basque Country, Spain), in the month of March. The decrease in flow throughout the mountain range is more clearly manifested when the period is reduced to 1990-2013. This negative trend becomes more pronounced, even on an annual scale, when analyzing projections of annual precipitation for the middle and end of the century, especially in the western part of the Pyrenees, while in the eastern part, especially in Catalonia (Spain), an increase is observed, which will also be reflected in the average annual flows (Beguería et al., 2023a). CLIMPY, another project from OPCC, concluded that the projections for the next seventy years do not showed a significant trend in the heavy precipitation index (CP95) at the mountain range scale; only a certain decrease could be detected in the south-eastern slope (Catalonia, Spain) and a certain increase in the northern and western parts (French basins, and Navarre and the Basque Country in Spain) (Amblar-Rancés et al., 2020). In this context arises the question about extremes, and specifically, about floods.part. One of the objectives of PIRAGUA was the analysis of floods in the entire Pyrenean region, where flash floods, can have a great direct impact on both the fixed and floating population, as well as on water services and energy resources. Some examples are the catastrophe at Camping las Nieves, in Biescas (Aragón, Spain), on August 7, 1996, in which 87 people drowned (García-Ruiz et al., 1996); the June 2013 floods with catastrophic damages in Spain and France (https://hepex.org.au/flash-floods-in-the-french-western-and-central-pyrenees-17-19-june-2013/); or the floods produced on 7 November 1982 (Trapero et al., 2013) that affected the three Pyrenean countries. The recent death of two people who were canyoning in the Pyrenees of Aragón (Spain) on September 2, 2023, when a flash flood event occurred is another example of this type of event that most people are unaware of. .However, until now there is no database or flood catalogue that specifically covers the Pyrenean regions, and even less so, the Pyrenees massif as a whole. For this reason, in the same way that the final objective of FLOODHYMEX (Llasat et al., 2013) was to cover the entire Mediterranean region, it was decided to create a similar database for the Pyrenees, but that included all types of flood episodes. The aim of this article is to present the first systematic database of flood episodes covering the entire Pyrenees massif, for the period 1981-2015, analyze the trends in light of the most recent articles (Clavera-Gispert et al., 2023), and characterize the weather types favourable to these flood events. This database is available at http://hdl.handle.net/10261/270351 (Llasat et al., 2022). Following the introduction of the study area, the structure of the base, the criteria followed for its construction, and the sources of information used are shown. The spatial and temporal distribution of flood episodes, both in the massif and the administrative regions, as well as the weather types, are then analysed. The paper ends with conclusions and discussion, where some adaptation measures are also commented.

l.30 Could you provide references or URLs for these two databases?

All the references and URLs to databases have been included in the caption of Table 1.

Table 1. Main characteristics of the study area. N.munic.: number of municipalities; Total pop.: total population; GDP: mean Gross Domestic Product for the region for the year indicated in the table ; *: value relative to the part of the region that belongs to the Pyrenees. CNIH: Catálogo Nacional de Inundaciones Históricas (National Catalog of Historical Floods); INE: Instituto Nacional de Estadística (National Institute of Statistics); PERICFN: Plan de Emergencia ante el Riesgo de Inundaciones en la Comunidad Foral de Navarra (Emergency Plan for the Risk of Floods in the Foral Community of Navarra) (https://gobiernoabierto.navarra.es/es/gobernanza/planes-y-programas-accion-gobierno/plan-emergencia-ante-riesgo-inundaciones-comunidad); EPRI: Evaluación Preliminar del Riesgo de Inundación (Preliminary Flood Risk Assessment of the 2nd Cycle of the Eastern Cantabrian Hydrographic Area); CCR: Caisse Centrale de Réassurance (Central Reinsurance Company) (https://catastrophes-naturelles.ccr.fr/); ONRN: Observatoire National des Risques Naturels (National Observatory of Natural Risks) (https://www.georisques.gouv.fr/articles-risques/onrn/acceder-aux-indicateurs-sinistralite#summary-target-1); INSEE: Institut national de la statistique et des études économiques (National Institute of Statistics and Economic Studies) (https://www.insee.fr); CENMA-IEA : Centre d'Estudis de la Neu i de la Muntanya d'Andorra-Institut d'Estudis Andorrans (Andorra Centre of Snow and Mountain Studies-Andorra Studies Institute). GDP data have been obtained from https://Datosmacro.Expansion.Com/Pib/Espana-Comunidades-Autonomas (Spanish regions), https://fr.statista.com/statistiques/479490/pib-par-habitant-selon-regions-france/ (French regions), https://datosmacro.expansion.com/pib/andorra (Andorra).

l.34-35 “there are very few such episodes that have affected the Pyrenees Mountain region on the databases.” Please indicate which databases are concerned: databases from reinsurance companies? For enhanced clarity, maybe this sentence should be rather placed just after the sentence pointing out the limits of databases from insurers.

The sentence has been modified and placed just after the sentence pointing out the limits of databases from insurers. Please, see the new Introduction that I have included to answer a previous question.

l.38-39 please formulate more explicitly the regions concerned in each country, and if the whole Greece is concerned: “the Catalonia region and the Balearic Islands in Spain, the former Languedoc-Roussillon, Midi-Pyrénées and PACA (Provence-Alpes-Côte d’Azur) regions in France, the Calabria region in Italy, and the whole Greece.”

We have replaced our sentence for this one proposed by you.

l.46 GDP: please detail the acronym

GDP means Gross Domestic Product. It has been added to the text.

l.50 please specify the country (Spain I can imagine)

The region correspond to three countries: Catalonia, Aragon, Navarra and Basque Country, in Spain; Nouvelle Aquitaine and Occitanie in France; and Andorra. They have been added to the text.

l.51 where did this september 2023 event occur?

On 2 September 2023 a flash flood event in a canyon in the Pyrenees of Aragon produced the death of two people. We have modified the sentence in the new Introduction. You can see information about this in the following press news:

- https://www.heraldo.es/noticias/aragon/huesca/2023/09/03/el-canon-donde-murieron-los-dos-jovenes-multiplico-por-10-su-caudal-en-unas-horas-1675558.html (no se puede acceder sin registro)
- https://ub-mynews-es.sire.ub.edu/hu/document/00001541-20230903-000482/
- https://www.eldiariomontanes.es/sociedad/mueren-dos-barranquistas-huesca-crecida-rio-consecuencia-20230902185859-ntrc.html?ref=https%3A%2F%2Fwww.eldiariomontanes.es%2Fsociedad%2Fmueren-dos-barranquistas-huesca-crecida-rio-consecuencia-20230902185859-ntrc.html
- https://www.sport.es/es/noticias/sucesos/mueren-personas-barranco-huesca-plena-dana-91629690

l.54 do you mean a comprehensive database of damaging flood events?

Effectively, there is not any database of flood events that refers specifically to the Pyrenean Region. There are national databases, or some regional databases like INUNGAMA that covers the entire Catalonia, but none so far has focused on the municipalities that make up the cross-border region of the Pyrenees.

l.86 “For events that were not known, it was even more time-consuming to identify new events on the CCS database” I don’t understand this, could you please reformulate?

We agree with you that the phrase is not clear. The text refers to the fact that the analysis of the CCS database made it possible to identify other flood episodes that did not appear in the initial INUNGAMA database. The entire section “2.2 Sources of information and identification of flood events” has been modified as previously shown.

l.87 could you indicate here if the newspapers were systematically consulted for the whole period or just for the dates pre-identified from other source of data ? (I imagine the second option is the right one)

The INUNGAMA database, which was used for Catalonia, is built from the systematic and direct consultation of all La Vanguardia newspaper day by day. The part of PIRAGUA_flood corresponding to Catalonia has been created from this and updated for the project, and therefore comes from a systematic consultation of the Vanguardia, expanded with cases identified through the other cited sources that did not constitute news in the Vanguardia. In the other cases, specific news was sought. We hope, however, that the explanations and the new text that I have introduced above already answer all these questions, so I will not repeat them here.

l.92 rather “included in the “?

Done

l.95-97 please provide references and/or URLs for these sources.

Done. In the new table 1 all the URLs of the sources that are publicly available have been included

l.100-104 again here, a reference and/or URL would be useful.

In the case of Andorra data are not publicly available.

l.118 Please add here a sentence to clarify the meaning of "level" in table 1 "In table 1 the levels 1 to 3 correspond to the level of damage observed for different categories of assets: level 1 refers to possible .."

Thank you very much. The redaction of the paragraph has been improved to clarify the meaning of "level" and a new Figure have been added to explain the categories.

Table1: I think it is not necessary here to repeat four times this table. The explanation provided in the caption for the classification in the four categories is sufficient, and could be placed directly in the text.

In response to your comment and the comment of reviewer 1, Figure 3 has been created, which contains a table with the methodology followed, in order to create a tool that helps classify flood episodes based on impacts. Until now the decision had been made in a totally subjective way taking into account the definition of the different types of episodes. New figure, included in my previous answers to you, has been created.

l.123 It is not clear here how these additional categories (car swept away and fatalities) are combined with the four initial categories (ordinary – extraordinary – catastrophic – major catastrophic). For instance is a catastrophic event with fatalities classified in the category 2 or 5 ? Could you clarify this ?

A catastrophic flood does not necessarily have to produce casualties and vice versa, there can be casualties in any other category of flood, since it also depends on the place where the victim was and his/her vulnerability. Likewise, it is possible for an ordinary flood to sweep away vehicles, even if there is no overflow. This happens in streams that are usually dry and are used as parking. This is, therefore, additional information to the flood category. For example, in Aragon only 3 episodes involved cars, one of which was catastrophic, other extraordinary and other ordinary; in Catalonia, 6 episodes involved cars, of which 4 were ordinary and 2 extraordinary; in Andorra there were 9 of which 7 were ordinary and 2 extraordinary. However, as previously answered, the entire paragraph has been modified.

l.134-136 If possible, please provide references or URL for these sources of data.

Thanks for your comment. The revised paragraph with URLs is:

The number of flood events was represented at a municipal level using Geographic Information Systems (GIS), ArcGIS 10.4 and QGIS 3.10. Spatial analysis was carried out for all categories of flood episodes. To do this, for Catalonia it has been used the database of municipalities in shapefile format provided by the Cartographic and Geological Institute of Catalonia (ICGC) (https://www.icgc.cat/es/Administracion-y-empresa/Descargas/Capas-de-geoinformacion/Divisiones-administrativas). For the other regions, the database of municipalities and regions in the Geographic Information System of the European Commission (GISCO) has been used, which is part of Eurostat (Eurostat https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/administrative-units-statistical-units/countries). Regarding the study area, it has been used the defined delimitation in PIRAGUA (OPCC) in shapefile format (https://www.opcc-ctp.org/en/geoportal).

l.139-140 Could you please describe here in more details the variables used for trend analysis: number of events per year? Number of events per season and per year? Number of events per category and per year? .

We thank the reviewer for this suggestion. We have expanded the description within these lines to include more information on the variables used in the trend analysis (by moving some information that was at the end of this section and complementing it). The revised section is:

3.3 Temporal analysis

The temporal analysis includes the monthly evolution of the events, in average, and the study of the possible annual trends. These analyses were carried out for the Pyrenees as a whole, as well as for the regions of Catalonia, Andorra, Aragon, the Basque Country, Navarre, Aquitaine and Occitanie. Likewise, for the severity of flood events, their evolution was studied considering the total number of events of each category per year (0, ordinary; 1, extraordinary; 2, catastrophic; or notable -combined number of extraordinary and catastrophic).

A linear regression was used to obtain the trend, while Mann-Kendall test was implemented to check its significance (Mann, 1945; Kendall, 1975). The Mann-Kendall test states as a null hypothesis (H0) that there is no monotonic tendency in the series, while the alternative hypothesis (Ha) is that there is trend (positive or negative). This is a non-parametric test, and it can therefore be applied to all types of data regardless of the underlying probability density function. In the present study, it was established that a trend is significant when the p-value of the Mann-Kendall statistic is below 0.05 ($p < 0.05$).

> l.153 "was then averaged on a daily basis" Do you mean here that the fields were temporally averaged for each calendar day ? This seems surprising since the considered fields may largely vary within one day. I think a clarification and a justification are necessary here.

Sorry for the misunderstanding. We did not average each calendar day, but we converted our 6-hourly data to daily by calculating the daily average. We have rephrased it in the text to be clearer. The revised text is:

The weather types associated with each flood episode have been classified using the mean sea level pressure (mslp) and the geopotential height at 500 hPa (z500), obtained from the ERA-5 reanalysis (Hersbach et al., 2020) in its native resolution (0.25°) for the geographical domain 20°W-20°E, 30°N-60°N. The original hourly data spanning from 1981 to 2015 were averaged on a daily scale to compute the synoptic classification described below.

> l.150 – 171 I think a figure would be useful here to illustrate how many categories were used, and how the mslp and z500 fields differ within each class (for instance through a reference to fig 16).

Thank you again for your comment. We have included a new figure showing the amount of variance explained by each principal component. This figure (now Figure 4, that is showed below), called scree plot, was just described in the text but not provided. We hope it helps you to understand the process of selecting components.

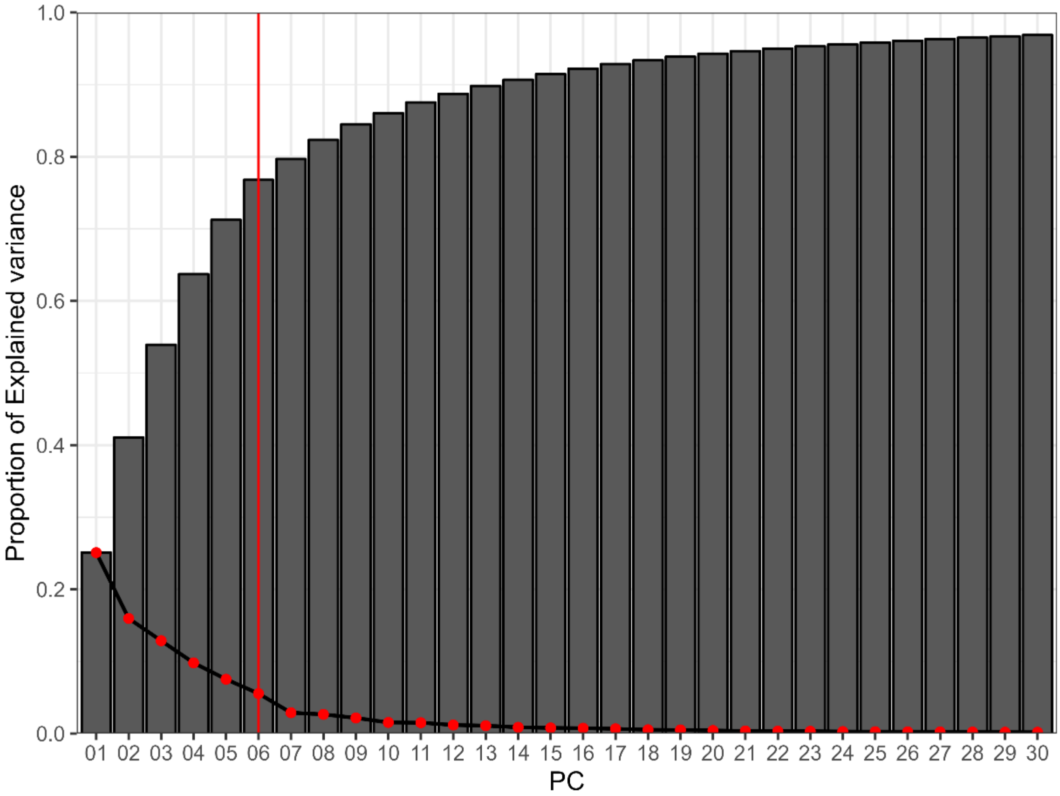

Figure 4. Scree test for the first 30 principal components (PCs). The red dots show the explained variance (%) for each principal component, while the grey bars show the cumulative explained variance. The red vertical line indicates the cut off PC. Thus, 6 PCs were retained accounting for the 78% of the total variance.

l.178-179 The high difference in the number of events depending on the considered country is rather surprising, particularly the low number of ordinary events recorded for France. This difference may be related to differences in the sources of data used for each country, with possibly a different level of detail and comprehensiveness in each. But this does not seem to be confirmed by fig.2 that shows a relatively similar frequency of events at the municipality scale for France and Spain (but a higher frequency for Andorra). I think this question of representativeness of inventory should be discussed here.

Following your comments, we have modified the text.

Table 4 has been provided in order to summarise the information that will be analysed in this section. It should be noted that the same event can affect more than two regions. This is why we have calculated the total number of times that the different Pyrenees regions have been affected by floods, TOTAL, and the total number of episodes that have affected the massif, TOTAL ep (considering that an episode that affects more than one region is counted only once). In this article, it is considered that those floods that occur on the same day are related to the same meteorological synoptic situation, and, therefore, it is the same episode that has produced floods in different places. This clarification is necessary because in other articles (i.e. Barriendos et al, 2019; Gil-Guirado et al., 2019) the criterion used is based on the sum of all the locations where flooding has occurred. If it would be considered the number of times the regions have been affected by flood events, the figure of 242 would be obtained, but if the criteria just explained is taken into account, it is concluded that the Pyrenees massif was affected by 181 flood episodes between 1981 and 2015. Of these events, 128 affected the Spanish part, 43 affected the French part, and 46 affected Andorra. Some of the events were common to two or all three countries or they affected different regions from the same country, with a total of 41 “transregional” episodes. One example was the flood event that occurred between

June 17 and 19, 2013, that affected Spain and France. In Catalonia, the municipalities with the greatest damage due to the 2013 event were Salardú, Arties, Escunhau, Vielha, Bossòst, and Les; in Aragon, it was Cerler, Castejón de Sos and Benasque; in Aquitaine, there was catastrophic damage in Lourdes and Arreau (Hautes-Pyrénées), Nay (Pyrénées-Atlantiques) and Saint-Béat (Haute-Garonne). Some towns were isolated due to road damage, landslides or rock falls. Numerous bridges, some buildings and campsites were totally or partially destroyed by the violent floods that carried rocks and remains of vegetation. Numerous houses and crop lands were flooded, causing cuts in all types of supplies. It was, therefore, a flood event of category 3 (major).

Figure 5 shows that the highest concentration of flood episodes occurs in Andorran municipalities and in the easternmost area of Occitanie and Catalonia. Some municipalities in Aragón and Navarra also stand out, while in the Basque Country and Nouvelle Aquitanie, no municipality have recorded more than 7 episodes of flooding. The region with the highest total number of flood events was Catalonia (66), followed by Andorra (46), while the lowest number was recorded in the Basque Country (16) (Fig. 6). Andorra is the region that records the highest percentage of ordinary floods (67.4%) although the absolute maximum corresponds to Catalonia. This regional difference may be related to both the orography and the meteorological disturbances causing intense rains, which will be discussed later. The highest number of catastrophic flood events was recorded in Nouvelle Aquitaine, followed by Occitanie and Aragón.

We cannot forget, however, that it is possible that some ordinary floods in France have gone unnoticed, as we have explained in section 2.2. This is why figure 7 has been constructed. It shows the distribution by municipality of flood events with notable damage (that is, they were extraordinary or catastrophic). The distribution hardly changes with respect to figure 5, and only the maxima of some municipalities are smoothed out. Of the 181 flood events, 52% produced notable damages in one or more of the Pyrenean regions. It is observed that notable flooding events are concentrated above all in the municipalities of the Pyrenees closest to the Mediterranean, both on the Spanish and French sides. The central part of the Spanish Pyrenees also stands out, located at the foot of the highest mountains. Pamplona (Aragón) and Llançà (Catalonia) have been the municipalities with the major number of flood events (17 and 16, respectively). For the period 1996-2015, the number of flood episodes in both regions becomes 9 and 11, respectively, with a compensation paid by the CCS that amounts to 18 M€$_{2015}$ and 1.1M€$_{2015}$, respectively. In the same period, Vielha (Catalonia), which after Pamplona is the municipality to which the CCS has paid the most, collected €9.9 M€$_{2015}$ in compensation for one episode. This difference is consequence of the major exposure of Pamplona, with a population of 195,853 inhabitants, in front of the 5,450 inhabitants in Vielha and 4,985 inhabitants in Llançà (year 2015). In the case of Vielha, the GDP is 170.2 M€$_{2015}$, practically double that the GDP of Llançà, with 91.9 M€$_{2015}$ that partially explains the different impacts between both Catalan villages, added to the fact that the 2013 flood in the Garonne River was catastrophic in Catalonia and Occitanie.

> l.182 “It means that if the numbers of events that have affected each Pyrenean region are added, the result is 242 events.”

The sentence has been modified as you can see in the previous answer to your comments.

> l.183 A more simple formulation can be used here “In this article, it is considered that ..”

The sentence has been modified following your proposal. Thank you.

> l.192 To clarify please mention explicitly which municipality was hit by the 2013 Garonne river catastrophic flood.

In order to answer your question we have added the following paragraph:

One example was the flood event that occurred between June 17 and 19, 2013, that affected Spain and France. In Catalonia, the municipalities with the greatest damage due to the 2013 event were Salardú, Arties, Escunhau, Vielha, Bossòst, and Les; in Aragon, it was Cerler, Castejón de Sos and Benasque; in Aquitaine, there was catastrophic damage in Lourdes and Arreau (Hautes-Pyrénées), Nay (Pyrénées-

Atlantiques) and Saint-Béat (Haute-Garonne). Some towns were isolated due to road damage, landslides or rock falls. Numerous bridges, some buildings and campsites were totally or partially destroyed by the violent floods that carried rocks and remains of vegetation. Numerous houses and crop lands were flooded, causing cuts in all types of supplies. It was, therefore, a flood event of category 3 (major).

> l.202-203 Figure 3 and table 2 seem to confirm that the inventory of ordinary floods is incomplete in Occitanie, Nouvelle Aquitaine, and Aragon regions (see my remark above). I think this could be stated more explicitly here, and maybe some reasons for this could also be advanced country (for France, I think events are recorded only if considered as having exceeded a 10-year return period).

Both figure 3 and table 2 have been improved, and the text referring to them has also been improved.

Section 4.1….” We cannot forget, however, that it is possible that some ordinary floods in France have gone unnoticed, as we have explained in section 2.2. This is why figure 7has been constructed. It shows the distribution by municipality of flood events with notable damage (that is, they were extraordinary or catastrophic). The distribution hardly changes with respect to figure 5, and only the maxima of some municipalities are smoothed out. Of the 181 flood events, 52% produced notable damages in one or more of the Pyrenean regions. It is observed that notable flooding events are concentrated above all in the municipalities of the Pyrenees closest to the Mediterranean, both on the Spanish and French sides. The central part of the Spanish Pyrenees also stands out, located at the foot of the highest mountain”

Section 2.2…” For Nouvelle Aquitaine (AQ) and Occitanie (OC), the databases of the Central Reinsurance Company (Caisse Centrale de Réassurance – CCR) and the National Observatory of Natural Risks (Observatoire National des Risks Naturels - ONRN) were used to create PIRAGUA_flood. In this case the information was completed in basis to the extreme rainfall records of Météo France. This ensured that all episodes that produced notable damage were included, although it is possible that some minor flood events with little damage have gone unnoticed”

> l.204 I think focusing on extraordinary and catastrophic floods is the good choice here, provided the doubts on the inventories of ordinary floods.

It is true that most of the discourse in the article will focus on notable flooding episodes. However, despite we are aware that some minor floods on the French side may not have been captured in the database, we consider it important to retain the information from ordinary floods, as they provide useful information to identify cross-border events, partial trends, etc. From a certain point of view, the fact of including the ordinary flood events in the database is one of the added values of the PIRAGUA_flood database. In this way, database users will be able to have information that is not easy to find.

> l.223 I do not see this information of 39 victims in November in table 2 or other figures. Maybe an histogram showing the seasonality of floods and victims would complement usefully the information provided in table 2 (this could be grouped with figure 12).

We have modified old Figure 12 (new Figure 8) to include the monthly evolution of fatalities for the different regions.

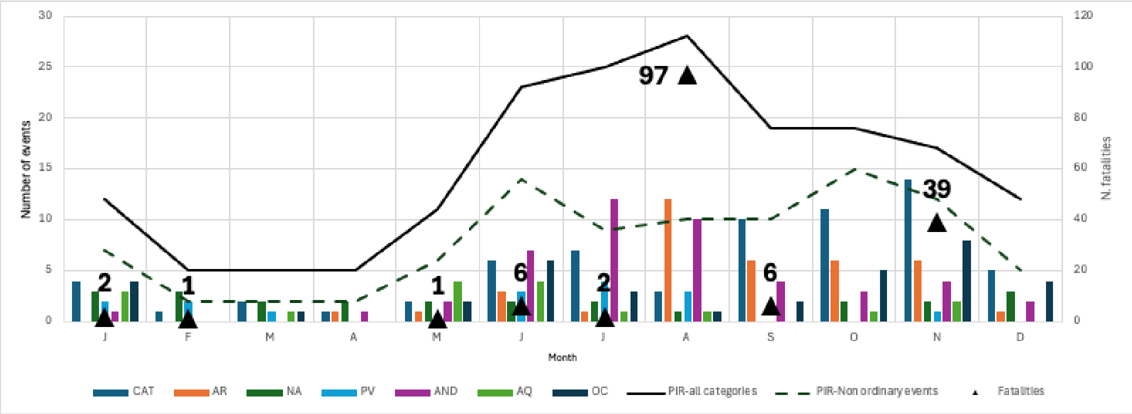

Figure 8: Monthly distribution of the total number of flood cases for the different regions. The solid line shows the entire Pyrenees-POCTEFA region, and the dashed line shows the number of significant events (period 1981-2015). The triangles indicate the total number of casualties in the entire study area for each month, the value is included next to the symbol.

l.241-242, 252-253, 264-265 Please mention here that the compensation amounts stand for the whole regions.

Given that the CCS only compensates for damage in the Spanish part, it is not possible to know the damage related to the entire Pyrenees since it has not been possible to have this type of systematic information for the other regions. However, taking into account your comments and those from the first reviewer, the entire paragraph has been modified.

4.2 Regional flood events distribution

(…) Although it is true that the costliest flood event recorded in Spain in that period took place in the Basque Country, in August 1983, the greatest damage occurred around the coastal estuaries, outside the Pyrenean region. Precisely, if the economic costs are taken into account, the CCS paid a total of €33.4 million updated at 2015 (M_{2015}) in flood compensation in the Catalan Pyrenean Region in the period 1996-2015, with the Val d'Aran being the most compensated region (a recreation and ski area with luxurious urbanizations near the river), mainly due to the June 2013 event that also affected Aragón and the French Pyrenees (Table 7). For the same period, the CCS paid a total of €15.2 M_{2015} in flood compensations in Aragón, mainly due to the flood events of August 1996 (the Biescas case), that also affected Andorra, and the flood event of June 2013. The CCS paid a total of €65.8 M_{2015} in flood compensation in Navarra, of which about €18 M_{2015} went to Pamplona and €5.5 M2015 went to Baztan. The CCS paid a total of €28.1 M_{2015} in flood compensation in the Basque Pyrenees, of which the largest amounts went to Tolosa (19.525 inhabitants, the most important city in the region).

Figures 2, 3 and 5-6-7: the color scales used in the maps showing the number of floods per municipality could be homogeneous among the different figures. This would confirm the consistency between the figures and facilitate the comparisons.

Figures 2 (new 5) and 4 (new 7) have been modified and we have used the same scale for both. Old figures 5, 6 and 7 have been deleted because they did not provide new information (this is clearly seen in new figures 5 and 7), which has allowed the regional analysis to be reduced. We have already included the new figures in this letter.

l.274 and fig. 8 please keep the same name for Toulouse or Tolosa

Thank you for the observation. It was a mistake. They refer to Tolosa. Toulouse is another city in France.

> Section 4.2 and figures 5-11: this section (and the related figures) is rather linear and repetitive, and brings very limited new information if compared with table 2 and figures 2-4. I think adding a general figure of the CCS compensations at the same geographical scale as figures 2-4, and providing further comments in section 4.1 about the differences between regions based on table 2 and figures 2-4, would be largely sufficient.

Following your suggestion we have deleted figures 5 to 10, and synthetized section 4.2 as follows:

4.2 Regional flood events distribution

In the study period (1981-2015) there were 66 episodes in the Catalan Pyrenees in which the number of victims amounted to 21. Three episodes were catastrophic and 26 were extraordinary (Table 4). Figure 5 shows that the highest number of floods took place in the coastal foothills of the Pyrenees (16 episodes in the coastal municipality of Llançà, of which 62% were extraordinary) that confirms the strong role played by the entrance of Mediterranean air masses In Aragon there were a total of 37 flood events, of which 13.5% were catastrophic. In 4 of them there were flash floods that led to the evacuation or death of several people who were canyoning. The number of victims amounts to 97, 87 of whom died at the Las Nieves campsite (Biescas) in August 1996 (Ayala Carcedo, 2002). Aragon has the county with the highest number of flash floods in the Pyrenees and it is Sobrarbe, where 26 events have taken place in 35 years. These are mainly events associated with thunderstorms in which the orography forces the rise and hinders the advance of convective systems, which can remain stationary in the same place (i.e. the Biescas case). The large number of torrents and dejection cones favors the production of flash floods. Given that these are very attractive mountain areas, it is possible that there are campsites, hikers or high-risk sportsmen and sportswomen, which increases vulnerability and exposure. The Navarre Pyrenees were affected by 24 events (17%, catastrophic) in which there was one victim. In this case, the damage is usually due to urban and peri-urban flooding, affecting its capital, Pamplona (203,418 inhabitants) that is the Pyrenean city with the largest number of recorded events (17). However, the most catastrophic episodes in Navarra have occurred in the Baztan valley, where numerous villages and small industries extend around the river. During the period 1981-2015 only 6 episodes of flooding (25% catastrophic) affected the Basque Pyrenees, with two victims. Most of them were concentrated in the eastern part of the region, near the Baztan valley. Although it is true that the costliest flood event recorded in Spain in that period took place in the Basque Country, in August 1983, the greatest damage occurred around the coastal estuaries, outside the Pyrenean region. Precisely, if the economic costs are taken into account, the CCS paid a total of €33.4 $million_{2015}$ (M_{2015}) in flood compensation in the Catalan Pyrenean Region in the period 1996-2015, with the Val d'Aran being the most compensated region (a recreation and ski area with luxurious urbanizations near the river), mainly due to the June 2013 event that also affected Aragón and the French Pyrenees (Table 7). For the same period, the CCS paid a total of €15.2 M_{2015} in flood compensations in Aragón, mainly due to the flood events of August 1996 (the Biescas case), that also affected Andorra, and the flood event of June 2013. The CCS paid a total of €65.8 M_{2015} in flood compensation in Navarra, of which about €18 M_{2015} went to Pamplona and €5.5 M_{2015} went to Baztan. The CCS paid a total of €28.1 M_{2015} in flood compensation in the Basque Pyrenees, of which the largest amounts went to Tolosa (19.525 inhabitants, the most important city in the region).

A total of 46 flood events were recorded in Andorra in the period 1981-2015, of which only 4.55% were catastrophic. It is a country of 79,824 inhabitants with a very high risk of flooding, especially because the most important towns and villages are surrounding the Valira River in a very narrow valley. The most important heavy rainfall events are usually due to Mediterranean perturbations that also affect Catalonia and/or Aragón (Table 7). The maximum number of flood events occurred in the municipality of Andorra la Vella (27), followed by Sant Julià de Lòria (18). In total, 43 episodes of floods affected the French side of the Pyrenees, of which Nouvelle Aquitaine recorded 17 events and Occitanie recorded a total of 36 events, with a percentage of catastrophic episodes of 35.3% and 13.9%, respectively. Ten of these episodes were common to the two regions. In Occitanie, the municipality with the most flood episodes was Montgaillard, with 13, while in Nouvelle Aquitaine the maximum was lower, with 7 events in Mauleon-Licharre. Both populations are located closer to the Atlantic than the Mediterranean, being exposed above all to disturbances from the west and northwest. As a whole, however, the municipalities located further east in Occitanie stand out, where floods are mainly associated with disturbances such as those affecting Catalonia and Andorra. It is noteworthy that all the municipalities in the French Pyrenees have recorded at least one catastrophic flood event, with the maximum recorded in the northeastern part, close to the Mediterranean.

> l.306 "The events are distributed.."

Done.

> l.315-317 and figure 12: I think showing distributions based on the total number of events is rather misleading here because of the possible heterogeneity between regions in the inventory of ordinary events. This is probably the reason why the joint distribution is unimodal close to the distribution of rainfall events in Spain. I think showing statistics based only on the extraordinary and catastrophic events would have been more relevant and representative here (i.e. the bimodal distribution).

The interest in maintaining ordinary floods in old Figure 12 (new Figure 8, already showed in our answers to the referees) lies in the fact that it shows a unimodal distribution, with a maximum in summer, coinciding with the studies that give the percentage of convective precipitation. This suggests that these are flooding episodes linked to intense and local rains of a convective nature, probably brief. On the contrary, the bimodal character would be a consequence of the integration of the autumn maximum typical of the Mediterranean region and the spring maximum, more typical of the central and western Pyrenees. This is explained in the revised text of the manuscript.

> l.320 theses results are rather related to Table 2 and fig.13 (not fig.12)

It has been modified. Thank you

> Section 6 and tables 3-4 bring very low added value if compared with section 5, and I do not see the interest to develop the cross-border episodes. I would suggest to remove this, or maybe to present just a table with the regions affected by the 41 "transregional" events (rather than cross border). I also think the development about the 1982 (figures 14 and 15) could be rather presented in the methods section (section 3.1) to illustrate the results of the flood inventory.

Old tables 3 and 4 showed the transnational flood events, and for this reason we have used the name of the countries. In these tables we don't show the cross-border events between regions. Considering your comment, we have completely modified both tables. Old Table 3 has been replaced by the following figure 9 that illustrates the monthly distribution of cross-border flood events.

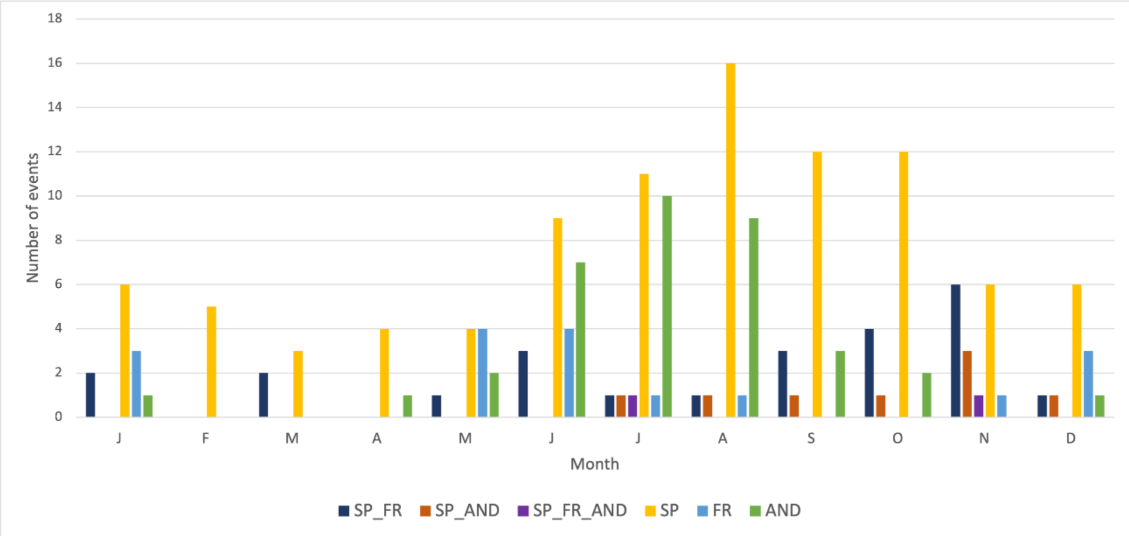

Figure 9. Monthly total number of flood events recorded in the Pyrenean Region (1981-2015), for each country (SP: Spain; FR: France; AND: Andorra) and for cross-border events.

After that, we have created a new table that includes cross-border (transregional) events:

Table 6. Number of events that have affected each Pyrenean region and number of events that have affected each pair of regions indicated by the intersection by them.

	CAT	AR	NA	PV	AND	OC	AQ
CAT	66						
AR	10	37					
NA	0	1	24				
PV	1	1	3	16			
AND	7	8	0	0	46		
OC	17	8	2	2	2	36	
AQ	3	4	5	4	1	10	17

Section 7: this section shows the temporal distribution of each of the weather types causing floods (figure 17), and some examples of the floods caused by each weather type are provided. I think some information illustrating the weights of each weather type in the generation of floods is missing here. It could be for instance a table similar to fig.17 but showing the distribution (or the numbers) of floods related to each weather type for each month of the year, and also the global distribution of weather type having caused floods. Also, some maps showing the number of floods in each municipality related to one weather type (or to groups of weather types occurring mostly in summer or autumn) would probably be informative about the regions affected for each category of weather type.

Thank you for your valuable suggestions. We have provided a new version of old figure 17 (Fig. 14) including a) the spatial distribution of flood days per CWT and b) both the relative and absolute (between parentheses) temporal frequency of this flood days per CWT and Month. We decided to work with larger regions than municipalities in order to observe the main spatial patterns across the Pyrenees. In the revised paragraph we have included new references to this figure and some little changes. See below the revised paragraph and new Figure 14:

Figure 13 shows the 12 weather types (WT) obtained from the combination of mslp and z500, and explaining practically 80% of the variance, corresponding to the flood episodes that affected the Pyrenees between 1981 and 2015. First of all, it should be noted that there is no significant trend in any of the WTs. The WT 1-, characterised by a marked depression to the NW of the Iberian Peninsula and a talweg is the most characteristic of the episodes affecting the Eastern and Central Pyrenees (Fig. 14a) in autumn (Fig. 14b). This favours the advection of warm and humid air from the Mediterranean in low levels, and feeds humidity from remote sources. This was the case during the November 1982 episode (Llasat, 1987), and is the case in a large number of the episodes of intense rainfall that take place in the Western Mediterranean (Insua-Costa et al., 2022; Miró et al., 2022). Note in Figure 13b that this type of weather shows its maximum frequency in the month of October, the month with the most episodes of flooding in the Pyrenees. The WT 1+ favours the entry of Atlantic air over the Western Pyrenees and, like the WT 1-, can lead to the passage of highly organised disturbances typical of winter or autumn (Fig. 14b), with notable rainfall accumulations in the western and northern part of the Pyrenees (Lemus-Canovas et al., 2019b) where most of the floods are recorded (Fig. 14a). In fact, the highest frequency is recorded in January (Fig. 14b). On the other hand, the dominant weather type in summer is WT 2- (Fig. 14b), which shows in the slight wave over the Iberian Peninsula, while on the surface the situation is relatively unclear. It would therefore be a situation favourable to isolated convection or poorly organised weather systems, typical of that time of year, but which can also result in some episodes of very intense rainfall, as also described in Lemus-Canovas et al. (2021). This is the situation that characterised the episode of Biescas (Aragon), which occurred on 7 August 1996, and the floods that affected the Basque Country and Aquitaine in August 1983, mainly concentrated in the southern half of the Pyrenees (Fig. 14a). The WT 3+ shows the formation of a mesoscale depression off the coast of Catalonia that results in instability and the E-SE air flow over the Eastern Pyrenees (Fig. 14a). The highest frequency is recorded in spring, specifically in June, a month that, as we have already seen, comes after October in terms of flood frequency (Fig. 14b). An example of this would be the floods of June 2013. These northern movements are usually associated with summer floods and can affect any area in the Pyrenees. Finally, it can be observed that in November the WT 4+ and WT 5+ dominate (Fig. 14b), both with a very marked groove over the Iberian Peninsula that will favour the vorticity to the east and the contribution of air flow from the Atlantic that feeds intense rainfall, especially in the easternmost sector of the mountain range (Lemus-Canovas et al., 2018). These WT are mainly associated with floods in the Eastern part of the Pyrenees (Fig. 14a). An example is the episode of November 2005, which had a serious impact on Catalonia.

The types of weather associated with cross-border episodes depend on the time of year in which they occur. Of the eight cases recorded between June and August (Fig. 10), seven have been characterized by WT 2-. In September, types WT 2- and WT 3- dominate. In October and November, which have recorded 16 common episodes, there is no dominant type of weather, and it is even the case that unusual types appear, such as WT 4-, characterised by a deep depression to the west of the British Isles that extends up to 500 hPa and even more, with a talweg that crosses the Peninsula from northwest to southeast.

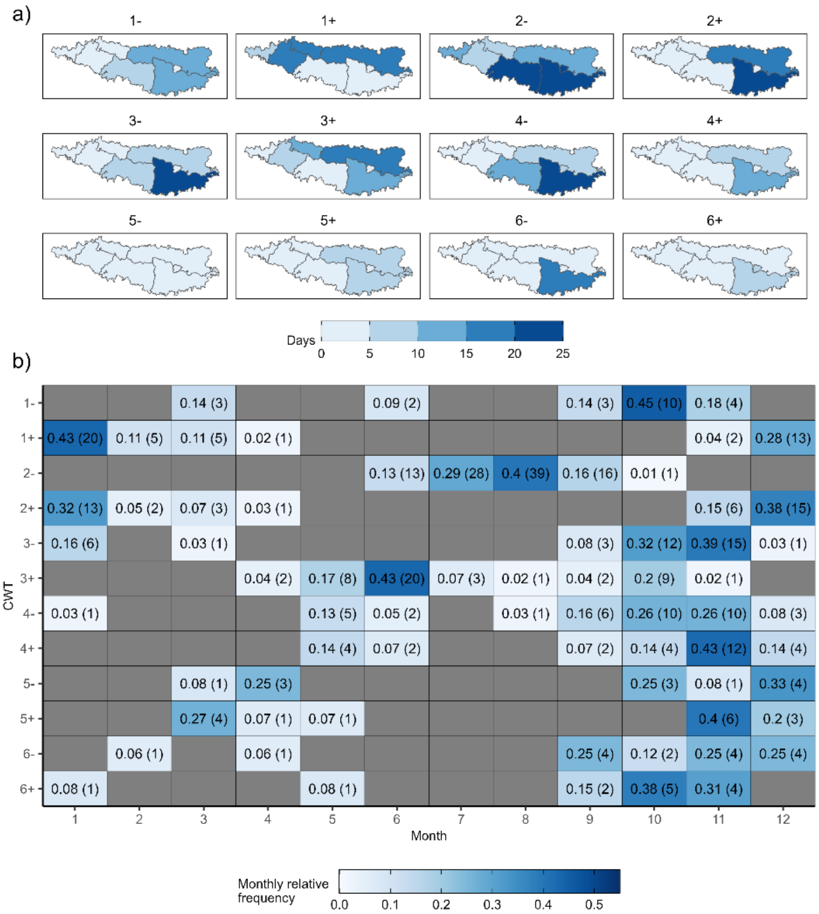

Figure 14. a) Number of flood days by weather type (WT) and Pyrenean region. b) Monthly relative frequencies of flood days by weather type and month. Between parenthesis absolute values are shown in flood days per month.

l.405-409 Again here the possible links with the limits of the flood inventory are not mentioned.

This paragraph of the Discussion has been modified. Thank you very much for your comment. The new paragraph is:

In this article, the first flood database integrating the entire Pyrenees massif and available to the public has been presented (http://hdl.handle.net/10261/270351). This database, PIRAGUA_flood, includes, at a municipal scale, all flood events that have affected each of the 1803 municipalities comprising this cross-border region between 1980 and 2015, of which 609 are Spanish, 1187 are French, and 7 are Andorran. Each event is characterized based on a scale that considers the impacts, providing information on these, including the number of victims, and in the Spanish case, compensations paid by the Insurance Compensation Consortium. Hydro-meteorological information is also included. The database has been constructed using information from press sources, official lists provided by various public agencies, scientific studies, and rainfall analyses. In the case of Catalonia and Andorra, systematic daily-scale information on all types of flood events, including those with lesser impact, has been available. For other regions, it is possible that some of these minor events may have gone unnoticed. However, since this information is typically difficult to obtain from any other source, it has been decided to maintain it. Additionally, these types of floods are becoming more common due to urbanization of the territory.

l.444 It is mentioned in table 2 and section 5 that both trends for the entire Pyrenean are not significant at 90%. This is in contradiction with what is stated here (conclusion).

We have addressed the identified discrepancy. The new paragraph in the Conclusions is:

The flood season starts in May in the Atlantic region and progresses to reach a maximum in autumn in the Mediterranean regions. Catalonia, Aragon, Navarra and Occitanie all share the month of October among the months that record the highest number of events. The Basque Country and Nouvelle Aquitaine share the month of June in common, while in Andorra is summer. If we only take into account events that caused notable damage (extraordinary and catastrophic episodes according to the nomenclature agreed here), a positive trend can be observed across the entire massif of 0.5 ev./dec., although it is not significant.. However, if the ordinary episodes are included, the trend becomes 0.84 ev/dec., and it is significant at 90%. When analysing in terms of communities, Nouvelle Aquitaine is the only region with a significant positive trend at 95% (0.34 ev./dec.). This positive trend in Nouvelle Aquitaine cannot be justified by the trend in the 90th percentile discharge, nor the lower percentiles, as shown in the study by Clavera-Gispert et al. (2023). To attribute this trend accurately, it would be necessary to conduct a study on more extreme discharge events and land use to associate it with an increase in vulnerability, exposure, or hazard. On average, projections also do not indicate an increase in intense precipitation in the Pyrenees (Amblar-Francés et al., 2020), but a recent study (Poncet et al., 2024) including the Mediterranean part of Occitania shows that the magnitude of the most intense floods will intensify.

Besides all the changes we have already introduced another important change. Following the proposal of referee 1, Appendix 1 has been eliminated and the information that it contained has been synthesized in two tables that have been introduced in section 3. Both tables are the following:

Table 2. Information and criteria used to fill out the EVENTS table.

Event codes	Integrated Event Code: numerical code used to identify the event that have affected one or more regions. Indicates the first and last day on which the event has been registered in the entire Pyrenean region.
	Event: Numeric field composed of the start and end dates of the event in the specific region
Dates	Start date: Indicates the beginning of the episode in the specific region.
	End date: Indicates the end of the episode in the specific region. Criteria: -The event starts when the rain starts in the region. -The event ends when the flood ends. -A subsequent episode is considered a new episode when there is more than one day (at least) without any of the previous conditions occurring.
Location information	Region: Indicates the administrative region affected by the event: Aragon (AR), Catalonia (CAT), Navarre (NA), Basque Country (PV); Occitanie (OC), Nouvelle-Aquitaine (AQ), Andorra (AND)
	Location 1: List of affected counties in the specific region
	Location 2: List of affected municipalities in the specific region
	Number of municipalities affected: number of municipalities that suffered damages in the specific region
	Affected area (Km^2): Sum of the total area of the affected municipalities, in Km^2
Meteorological and hydrological information	Ptotal (Loc), Pmax (24 h) (Loc) o P (h) (Loc) (mm): It indicates the maximum cumulated precipitation in all the event or/and the maximum precipitation in 24h in mm or/and the maximum rainfall intensity in mm/h and its duration. In the three cases the station where the value was recorded is indicated.
	Other meteorological data: Optional field to add more hydrometeorological information.
	Other weather phenomena: Other adverse natural phenomena occurred in addition to floods: landslide, debris flow, hail, snow, windstorm, tornado, snow melting, lightning.
	Affected drainage basins: List of affected river basins

	Maximum flow (m^3/s): Maximum instantaneous flow recorded indicating the river, gauging station and date, in addition to the average annual flow. If information is available for more than one river, it is included.
Event impact indicators	Category: The category of the flood event in the region according to the criteria described in section 3.1. There is a column for each category and supplementary categories

Table 3. Information and criteria used to fill out the MUNICIPALITIES table.

Event codes	Integrated Event Code: numerical code used to identify the event that have affected one or more regions. Indicates the first and last day on which the event has been registered in the entire Pyrenean region.
	Event: Numeric field composed of the start and end dates of the event in the specific region. The same code that identifies the event in the “Events” table must be used.
Category	Event category: The category of the flood event in the region according to the criteria described in section 3.1. There is a column for each category..
Municipality and region identification	MunicipalityID: Code (NATCODE, INSEE or equivalent) of the municipality affected by the floods. Each row is for a municipality, which means an event can have more than one row.
	Location name: Name of the municipality.
	Region: region to which the municipality belongs
Information about victims	Deceased: Total number of fatalities in the municipality (if any).
	Gender and age of victims: When information is available, the gender and age of each victim is indicated.
	Causes: A brief description of the causes of death.
Other information	Other information: Supplementary information that is not covered in the other fields.

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