Answers to referee#2's comments:

We thank the reviewer for their very valuable comments. Below are mentioned responses to them point-by-point:

General comments

The results are interesting but not unequivocal in my opinion. The authors also correctly mention the role of other factors such as flood vulnerability, land use but they do not specify them (what happened when the flood frequency changes).

At the moment it is not possible to identify the weight of the different factors involved in flood evolution, and it remains as a major challenge for future research (see, for instance, the paper from Hall et al., 2014, recently published in HESS). However, attending your comments as well as those other ones from the first referee, we have introduced the following paragraph in the Introduction section:

"Historical flood evidences are mainly based on the impact descriptions and, consequently, they refer to the floods as a holistic risk, being difficult to separate the "natural" causes from the rest. The flood chronologies that can be constructed from instrumental records and flow series for Europe do not usually extend further back than the 19th century (the 20th century for Spain). Flood historical records can arrive until the 14th century, except for those in Italy dating from the Roman Empire. Besides this, information density in past is heterogeneous, not only due to the lack of records (i.e. Macdonald, 2014), but also due to the relative youth of the science that encompasses historical climatology with the modern understanding of climate dynamics, meteorology and hydrology (Glaser, 1996; Camuffo and Enzi, 1996; Brázdil et al., 1999; Lang and Cœur, 2002). The major documentary historical sources containing climatic information and details of its effects are local and state government records, religious collections, private collections, notaries' archives and taxation records (Barriendos et al., 2003; Brázdil et al., 2014). Whenever possible, the historical flood classification should be based on discharge estimates, with a sensitivity analysis to assess the specific errors of the hydraulic model for the conversion of historical flood levels into discharge (Brázdil et al., 2006; Herget et al., 2014). On the contrary, in order to have the longest possible flood series, a scale of event magnitude can be proposed using the effects of the floods on the river channel system and surrounding areas. This is the approach more commonly used (Llasat et al., 2005; Barriendos et al., 2014; Retsö, 2014). In this sense, the objective of the FLOODCHANGE project is to improve at European scale the built of long historical flood records in order to build a flood-change model (http://floodchange.hydro.tuwien.ac.at/deciphering-river-flood-change/). We would like to address the reader to the papers published in this special issue to find more details about historical floods data and their analysis (Kiss et al., 2014)."

Barriendos, M., Ruiz-Bellet, J.L., Tuset, J., Mazón, J., Balasch, J.C., Pino, D., Ayala, J.L.: The "Prediflood" database of historical floods in Catalonia (NE Iberian Peninsula) AD 1035–2013, and its potential applications in flood analysis, Hydrol. Earth Syst. Sci. Discuss., 11, 7935-7975, 2014.

Brázdil, R., Kundzewicz, Z.W., and Benito, G.: Historical hydrology for studying flood risk in Europe, Hydrolog. Sci. J., 51, 739–764, 2006.

Brázdil, R., Chromá, K., Řezníčková, L., Valášek, H., Dolák, L., Stachoň, Z., Soukalová, E., and Dobrovolný, P.: The use of taxation records in assessing historical floods in South Moravia, Czech Republic, Hydrol. Earth Syst. Sci., 18, 3873-3889, 2014.

Glaser, R.: Data and methods of climatological evaluation in historical climatology, Hist. Soc. Res., 21, 56–88, 1996.

Hall, J., B. Arheimer, M. Borga, R. Brázdil, P. Claps, A. Kiss, T. R. Kjeldsen, J. Kriaučiūnienė, Z. W. Kundzewicz, M. Lang, M. C. Llasat, N. Macdonald, N. McIntyre, L. Mediero, B. Merz, R. Merz, P. Molnar, A. Montanari, C. Neuhold, J. Parajka, R. A. P. Perdigão, L. Plavcová1, M. Rogger, J. L. Salinas, E. Sauquet, C. Schär, J. Szolgay, A. Viglione and G. Blöschl, 2014: Understanding Flood Regime Changes in Europe: A state of the art assessment. Hydrol. Earth Syst. Sci., 18, 2735-2772, 2014, www.hydrol-earth-syst-sci.net/18/2735/2014/ doi:10.5194/hess-18-2735-2014

Herget, J., Roggenkamp, T., and Krell, M.: Estimation of peak discharges of historical floods, Hydrol. Earth Syst. Sci., 18, 4029-4037, 2014.

Kiss, A., Brázdil, R., and Blöschl, G. (eds.): Floods and their changes in historical times - a European perspective, HESSD special issue, 2014.

Macdonald, N.: Millennial scale variability in high magnitude flooding across Britain, Hydrol. Earth Syst. Sci. Discuss., 11, 10157-10178, 2014.

Retsö, D.: Documentary evidence of historical floods and extreme rainfall events in Sweden 1400–1800, Hydrol. Earth Syst. Sci. Discuss., 11, 10085-10116, 2014.

Moreover, the observed trends in frequency of floods may be significantly influenced also by trends in frequency of available data which is not enough discussed in the paper. In my opinion, it could explain the fact that trends in catastrophic floods are substantially less significant in comparison with extraordinary floods (= category 2) because representation of the latter ones is more sensitive to quality of data sources (it seems to be obvious if comparing for example Figs. 6a and 6b).

We agree with your observation. This potential heterogeneity due to the changing criteria in flood historical records and in available data was already discussed in Barnolas and Llasat (2007). It is a typical problem that usually affects natural hazard series, as the own IPCC (2012) recognises. The problem is especially relevant when it is referred to minor floods, mainly the ordinary ones. This is one of the reasons for which we only analyse catastrophic floods in the second part of the paper. However, and following your comments, we have added a reference to a recent paper in which an homogeneous period from the point of view of data sources and criteria, has been analysed

"... whereas extraordinary floods have seen a significant increase, especially from 1850 onwards (Fig. 3b). **These trends are similar to these ones obtained when the homogeneous series 1981-2010 are analysed (Llasat et al., 2014).** Extraordinary floods are responsible for the total increase in flooding in Catalonia (Fig 3c)."

Llasat, M.C., R. Marcos, M. Llasat-Botija, J. Gilabert, M. Turco, P. Quintana. Flash flood evolution in North-Western Mediterranean, Atmospheric Research, 149, 230–243, 2014.

The results are compared with central and Eastern Europe but without any remark on the fact that floods can be due to thawing there – such events can be linked to climate factors in very different way.

It is true that floods in Central and Eastern Europe are mainly due to thawing, and this is not the case for Catalonia. We have compared our results with the floods in those regions of Europe, because there are a lot of works concerning floods in that area and anomalous climate periods are more or less common in all Europe at the same time. However, catastrophic floods in that zone of Europe are related to anomalous high snow accumulation in late spring whose melting with abundant rainfalls cause significant flooding. This anomalous accumulation is linked to climate anomalies and these anomalies also affected the whole continent at the same time. Besides this, in the last discussion about the influence of NAO and solar variability we comment the different atmospheric patterns related to floods in the Central/Northern Europe and the South. A new sentence has been introduced in the new version of the paper in order to clarify the referee's concern as follows (in bold letters):

"…found in Catalonia. **However, most catastrophic floods produced in Central and Eastern Europe are due to thawing in late spring after anomalous high snow accumulation combined with abundant rainfalls. This is not the usual case for Catalonia, but periods with a high frequency of catastrophic floods in both zones are as a result of climate anomalies affecting the whole continent.**

Trend analysis of temporal evolution for…"

Specific comments

The title does not inform which Mediterranean Region is the paper about – it should be more concrete

We have changed the title as follows:

"Evolving flood patterns in a Mediterranean region (1301-2012) and climatic factors. The case of Catalonia".

Page 9149, line 26: Words "very convective" are colloquial in my opinion.

We have changed them by "**highly** convective".

Page 9150, line 24: Even if Barcelona is a good representative of precipitation in the region (not proved but Fig. 8 suggests it), it should be mentioned that especially flash floods can be due to only local rainfall that can miss the city.

This sentence has been extended to include referee's suggestion as follows (in bold letters):

"Barcelona is a good representative for precipitation behaviour along the Catalan coastal region, **despite the fact that some flash floods occurred in it can be due to local rainfall that can miss the city**. This series is the longest set of…"

Page 9153, line 3: "Inter-annual" implicates that the authors compare individual years which is not the case here; "seasonal" would be probably better. Additionally, I am not sure whether the word "inter-decadal" (line 12) is used correctly for variability among decades or the authors mentioned the variability among individual years within a decade.

Inter-annual has been changed by seasonal as the referee suggested. Additionally, the word "inter-decadal" is misused; therefore we have changed it by "**inter-annual**" which is more appropriate.

Page 9153, line 16: The study contains also twelve years of the 21th century.

We have included this comment in the sentence as follows (in bold letters):

"...mid-17th century, the beginning of the 18th century and the end of the 20th century **and the beginning of the 21st century**. On the other hand, seven different…"

Page 9154, lines 29-30: The statement seems to me not as unquestionable as it is presented.

We have changed the tense of the statement in order to show the referee's concern as follows (in bold letters):

"…and 2.6 years. The first **could be** related to the Gleissberg solar cycle (~70-100 yr) and the second to…"

Page 9155, line 6: One of the words "more" and "less" is redundant in my opinion.

Obviously both words are redundant. We made a mistake when wrote this sentence. The correct sentence is as follows (changes in bold letters):

"Autumn precipitation contributes **less** to annual precipitation than autumn floods contribute to the annual total, but it is…"

Page 9156, line 13-14: The increase of the correlation coefficient could be due to rather small number of episodes when rainfall exceeded the highest threshold. It could be the case also for the short period 1862-1892 (lines 20-21).

We have completely remade this part of the manuscript including the analysis of the 31-year moving correlations between rainfall thresholds and floods in order to clarify it and also following the suggestions made by referee#1 (in bold letters):

"In Barcelona, the temporal correlation **(Fig. 8)** between total annual floods and the number of days exceeding thresholds of 20 mm/d, 30 mm/d, 50 mm/d and 100 mm/d is relatively low for the 1854-2012 period, which shows the most significant correlation for the number of days exceeding 50 mm (+0.24). **The correlation between the previous thresholds and the catastrophic flood index also shows the same pattern.** Barrera et al. (2006) outlined that urban growth in the city of Barcelona has had an impact on flood vulnerability and **the flood frequency** from the 14th century onwards, especially from the late 19th and early 20th century. **This fact is corroborated when analysing the 31-year moving correlations for the above-mentioned variables for raw**

data (Fig. 8). Considering the total annual number of floods and number of days above 50 mm/d they reached values above +0.60 for 1936-1985, which could be considered as an homogenous period because the city drainage system did not experience significant changes (Martín-Pascual, 2009). The construction of water tanks, from 1990s on, diminished the correlation with the 50-mm threshold and improved the one with the 100-mm threshold arriving to +0.61. On the contrary, after the wall demolition and initial urban occupation of flood-prone areas, the 20-mm threshold shows the best correlations. This fact corroborates the strong sensitivity of rainfall threshold associated with floods to changes in vulnerability."

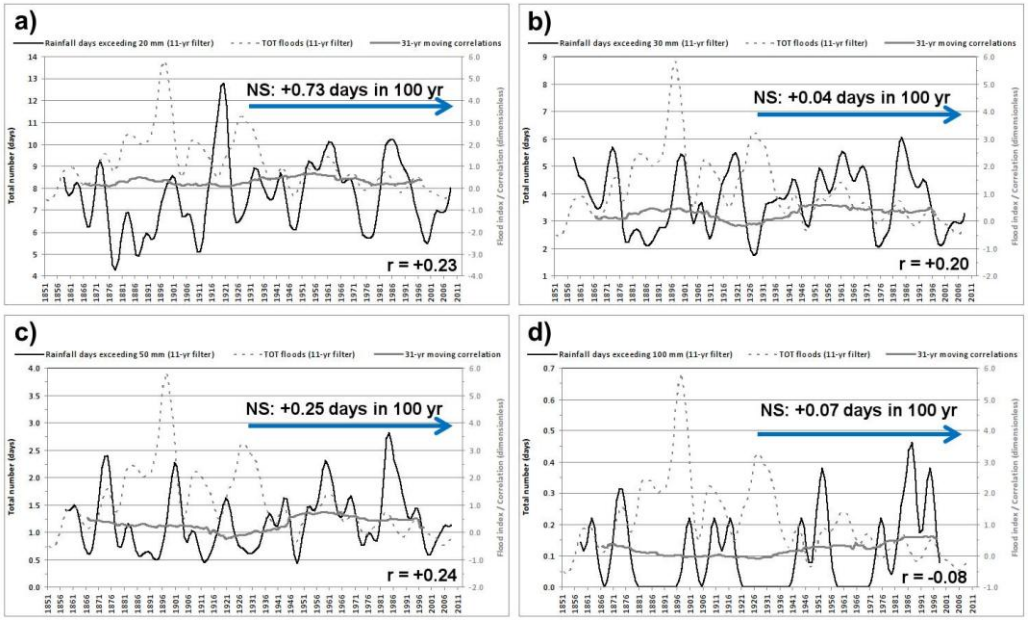


Figure 8. Temporal evolutions of total flood index series and the number of days exceeding a daily precipitation threshold for Barcelona (1854-2012): a) 20 mm, b) 30 mm, c) 50 mm and d) 100 mm. Data have been smoothed by an 11-year Gaussian low-pass filter. **The 31-year moving correlations between floods and the different daily precipitation thresholds are also displayed in each panel**. The results of applying a trend analysis in the number of days **and the temporal correlations between them and floods for all the period** are also shown.

Page 9156, line 24: "Various" would be probably a better word instead of "different" at the end of the line.

It has been changed.

Page 9158, lines 15-17: The presented relation is problematic: while the period of high flood frequency lasted 1591-1623, the solar activity maximum started only three years before the period finished. It can hardly support the hypothesis that increases coincide in both solar and flood activity.

We made a mistake when wrote this sentence. As it is written, this sentence does not make sense. The solar activity maximum did not start in 1620, it started in 1580 and finished in 1630. Thanks to your comment we have changed the year:

"…the most significant period of high flood frequency (bLIA) was recorded near maximum solar activity levels that started in **1580** at the beginning of the LIA, and during the Maunder Minimum…"

Page 9158, lines 26-28: I do not see any support for this statement in the text; the difference in the sign of the correlation coefficient does not express the strength of the correlation.

We have removed the last part of this statement and written more information in order to clarify it as follows (in bold letters):

"…in the mid-16th century and in the late Maunder Minimum (1675-1715), corresponding to periods with less solar activity. **On the contrary, Vaquero (2004) points to a major flood frequency in Tagus River (Iberian Peninsula) associated with maxima solar activity. This suggests that the regional component is very important. This fact is not strange if we consider the different circulation patterns associated with heavy rainfalls and floods (including snowmelt) and their potential seasonal shift for different periods.** Other authors…"

Table 1 and most of the figures: The data series are not of the same length; how authors deal with this problem in the evaluation?

Time period is not common to all the chronologies. We have maintained different periods in order to take benefit from the maximum available information for each location and increase the number of "observations".

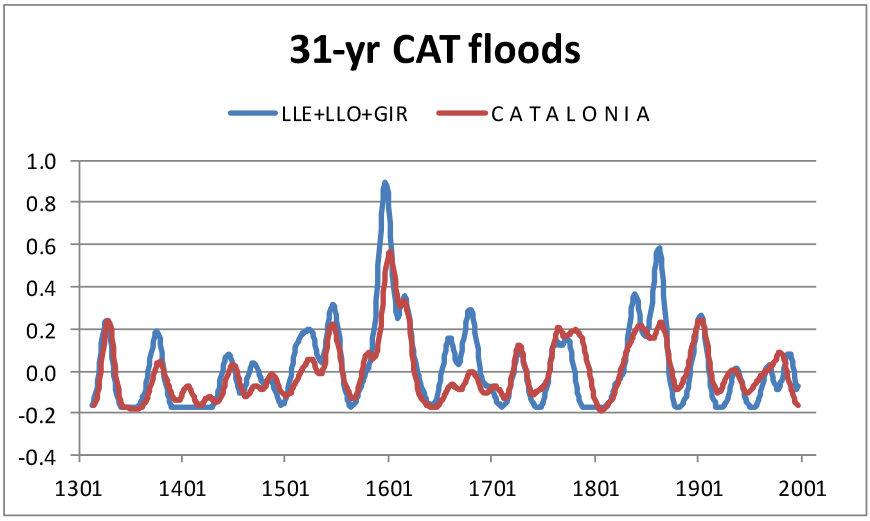
The final flood index series is an average from all flood series. This average has been obtained taking into account only the available data, so at the end of the final series there are more data to compute the final average value. However, due to the fact that the final flood index is based on individual normalised values we think that the addition of new data at the end of the final series do not significantly modify the average. Anyway, all data used in this work are the most complete at the moment in Catalonia related to historical floods. In addition, the only three chronologies beginning in 1301 are quite representative for all Catalonia, and the other flood chronologies only reinforce and complete the temporal behaviour of those three long series.

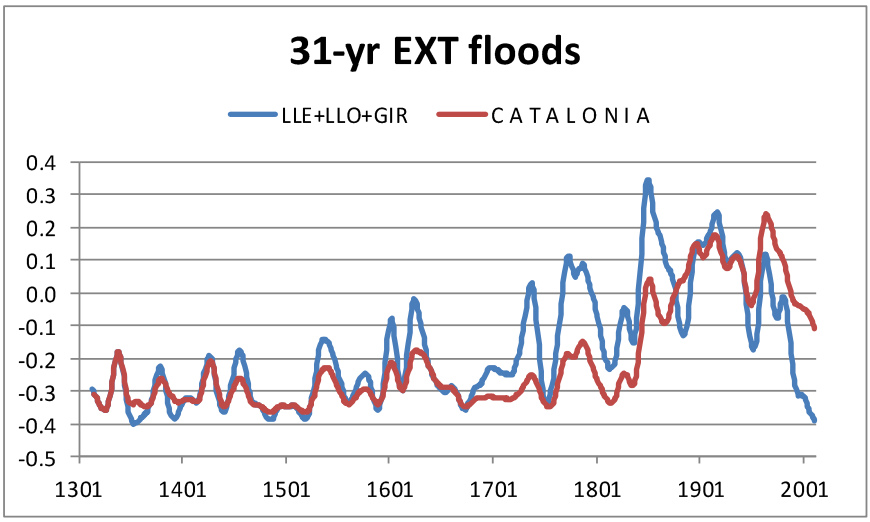
Our main goal is to identify periods with a high frequency of catastrophic floods rather than analysing temporal trends. If we only analysed the common temporal period for all chronologies (1739-2012 for all series, or 1671-2012 for all series except Mataró), we would be losing information.

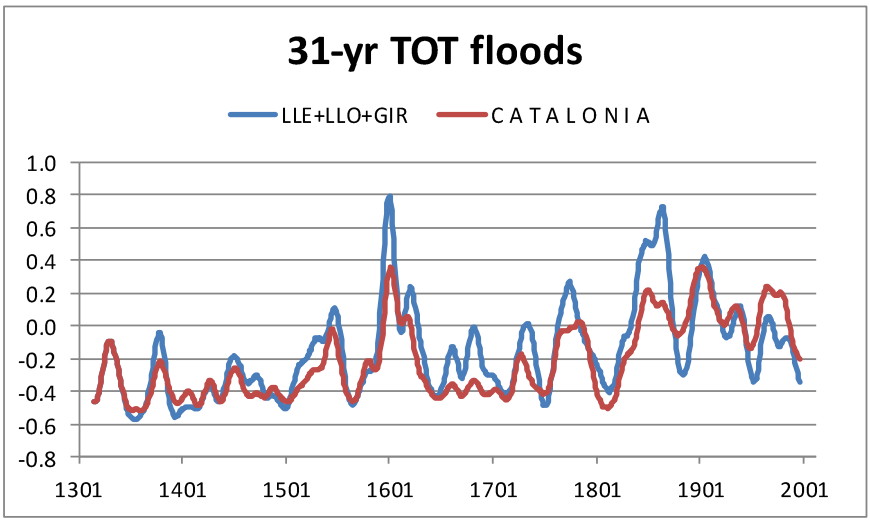
Homogeneity issues related to these data were analysed in Barriendos et al. (2003) and the introduction of new data in the last period does not any significantly change in homogeneity (not important changes in vulnerability have been produced in the last few years; Llasat et al., 2014).

If we only compute the final flood index from the three series beginning in 1301 (LLE=Lleida, LLO=Llobregat and GIR=Girona) the general pattern and flood behaviour is

quite similar to the flood series obtained from all chronologies, especially for catastrophic ones (see the following images):







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Technical comments:

I have not found the following references in the text: page 9165, lines 32-33; page 9166, lines 21-22; page 9168, lines 7-8; page 9169, lines 20-22; page 9170, lines 10-12.

All these references have been removed from the reference list. They came from a previous version of the paper and we forgot to remove them.