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Climate of the Past Discussions

Interactive comment on "Rogation ceremonies: key to understand past drought variability in northeastern Spain since 1650" *by* Ernesto Tejedor et al.

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Dear Editor, We very much appreciate the comments and suggestions made by the reviewers. Since both reviewers are concerned by the fact that we are using a quantitative approach with semi quantitative data, we will better explain the limitations of our proxy in the revised version (please see new version attached). We also clarify the nature of our data by performing an Empirical Cumulative Distribution Function. The derived drought indices can take values between 0 and 3 (see Fig. 2AB, included now in the manuscript), and thus can be considered as a continuous variable. In addition, as suggested by #Anonymous reviewer 1, we have now included a new paragraph in

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the manuscript showing the 'validation' of our data, including the new Figure 5, which we believe clearly shows the strength of rogation ceremonies as drought proxies. Lines 240-252; 'To better understand the relationship with the derive drought indices and the instrumental series, we used the longest instrumental precipitation and temperature series covering the period 1786-2017 (Prohom et al., 2012; Prohom et al., 2015) for the city of Barcelona and thus overlap the rogation ceremony's period from 1786 to 1899. The instrumental series was homogenized and developed including data from cities nearby and along the Mediterranean coast (see Prohom et al., 2015 for details). We then calculated the Standardized Precipitation Index (SPI, McKee et a., 1993) and the Standardized Evapotranspiration and Precipitation Index (SPEI, Begueria et al., 2014) and calculated spearman correlation between DIMED and the SPI/SPEI at different time scales including a maximum lag of 12 months covering the period 1787-1899. To further explore the relationship between the drought indices inferred from historical documents and the instrumental drought indices through time, we performed 30 and 50 years moving correlations.' Lines 310-319; 'The maximum correlation ($r=-0.53$; $p<0.001$) between the Mediterranean Drought Index and the instrumental SPI over the full 113-year period (1787-1899 AD; Fig.5C) is found for the SPI of May with a lag of 4 months (SPIMAY_4 hereafter). Slightly lower, though still significant correlation, is obtained when using the SPEI of May with a lag of 4 months (SPEIMAY_4) ($r=-0.50$; $p<0.001$, Fig.5D). The moving correlations between SPIMAY_4 and DIMED for 30 and 50 years (Fig.5A; Fig.5B) show high and stable correlation through the full period. The relationship with the SPEIMAY_4 is also high and stable throughout the overlapping period, although lower than with SPIMAY_4.'

We performed a cluster analysis to study meaningful groups of historical documents that share common characteristics. We agree with the reviewers that multiple cluster techniques will provide different results, but in this specific case we believe that the three clusters have spatial coherency (as commented in detail in the point by point response below).

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This is the Point-by-point response with which we respond to all suggestions and comments of the reviewers.

Anonymous reviewer 1. The paper aims to characterize the variability of droughts in NE Spain since 1650 using records from rogation ceremonies from 13 cities. This type of records have been used in the literature as proxy for droughts in the last years with success, as can be seen in the literature and is well reflected in the references of the manuscript. Most of those previous studies are focused on certain locations, but there have also been previous exercises analyzing jointly these records. The main novelty here is the use of cluster analysis to identify spatial patterns within NE using these rogation ceremonies.

Many thanks for the positive comments.

I have several major methodological problems in the type of treatment used in the manuscript that prevent me from acceptance. 1- For every location the authors generate and index which ranges from 0 to 3 depending on the frequency and type of rogations. According to the manuscript, the index is computed as a weighted average of the reports found for a given year between December and August.The weight depends on the type of rogation held, according to a given protocol. In my view this must be interpreted with caution due to different reasons. First the same value can be reached with different extremes. Thus, a value of 2 (moderate drought) can be obtain with one single record of level 2 or with two records: one rogation ceremony of level one and another one of level 3 (1x1 + 1x3)/2=2. The climatic difference is really relevant, since in the second case the drought should have been much more extreme than in the first one.

We appreciate the comments and understand the reviewer's concerns. We believe through the Empirical Cumulative Distribution Function analysis and the validation section we now assert the validity of the methods used to convert the categorical information to semiquantitative data. Please note that we have now changed quantitative by

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semiquantitative throughout the whole manuscript. We further extend the explanation of the limitations of our data in. Lines 371-380; 'Further limitations of converting qualitative information into quantitative data refer to the fact that, for instance, a drought index of level 2 does not necessarily imply a drought twice as intense as a drought index of level 1. This is an inherent limitation when dealing with historical documents as a climate proxy, and different approaches have been applied in the scientific literature (Vicente-Serrano and Cuadrat, 2007; Dominguez-Castro et al., 2008). In our paper, we follow the methodology proposed in the Millennium Project (European Commission, IP 017008) and demonstrated in Domínguez-Castro et al., (2012)'. To that extent, the ECDF helped understanding the nature of the historical documents when transformed into semiquantitative data which confirm that they can be treated as a continuous variable'.

This index is semi quantitative because the levels are assigned after analyzing the ritual and due to the lack of overlap with the instrumental record, it is just an assessment expressed in a quantitative scale.

Please see answer above.

Finally, the index is not linear, in the sense that a drought of level 3 should not necessarily be three times more intense than a drought of level 1. All these cautions should be taken into account when applying to the index built in the manuscript. The authors claim (I 249 for example), that they have obtained a continuous quantitative index, but these cautions are not mentioned in the text.

We have now extended the description of the drought index limitations including the following suggested changes, please see above. However, the fact that the correlation of the overlapping period between the instrumental and the regional DIMED is very high and stable over time suggests that the rogations ceremonies can be considered as a drought indicator. In such a catholic society, similar droughts throughout the territory would trigger similar religious acts, which at the same time cost money. The authorities

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and the church would not perform an expensive rogation ceremony of level 3, unless drought is severe, and the yearly harvest is in danger.

Next, a cluster analysis is performed to identify spatial patterns. According to the manuscript, there are three patterns: Mediterranean, Mountain and Ebro Valley. I think that this division does not make sense from the climatological viewpoint due to several reasons: - Lerida (other times called Lleida) and Cervera are two locations separated around 50 km, they are both included in the Ebro valley, at a similar distance from the sea and with no relevant mountains in between (see figure 1). On top, the pluviograms are very similar, check the Iberian climatologiacal Atlas, for instance (http://www.aemet.es/documentos/es/conocermas/recursos_en_linea/publicaciones_y_estudios/publicaciones/Atlas-climatologico/Atlas.pdf). However, Lerida is included within the Mountain cluster and Cervera within the Mediterranean one. This is difficult to understand. - Teruel, in the middle of the Iberian range, is included within the Mountain cluster, which is mostly composed by locations close to the Pyrenees. Teruel is around 400 km from the closest location in the cluster. Its precipitation regimen is poorly associated with those in the Pyrenees. Additionally, as can be seen in figure3, Teruel index is only significantly correlated with Barbastro and non significantly with the rest. - Gerona (or Girona, depending on the text or figure) shows similar problems with the rest of the Mountain cluster with 3 nonsignificant correlations and two very poor correlations (up to 0.22). Anyone familiar with the climate of Spain (as the authors) should be aware of these issues, that are also evident in figure 5. Consequently, I think that of physical meaning of the cluster is very poor and the patterns might be an statistical artifact.

We appreciate this a comment, and now have explained in the revised version. Lines 389-403; ‘In addition, the clusters might not only be collecting climatic information but also diverse agricultural practices or even species. For instance, Cervera and Lleida, sharing similar annual precipitation totals, belong to the Mediterranean and the Mountain Drought Indices respectively. Lleida is located in a valley with an artificial irrigation system since the Muslim period, which is fed by the river Segre (one of the largest trib-

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utaries to the Ebro river). The drought in the Pyrenees is connected with a shortage of water for the production of energy in the mills as well as to satisfy irrigated agriculture. However, the irrigation system itself allowed them to manage the resource and resist much longer. Therefore, only the most severe droughts, and even so in an attenuated form, are perceived in the city. Cervera, located in the mountains, in the so-called pre-littoral system and its foothills, has a different precipitation dynamic more sensitive to the arrival of humid air from the Mediterranean. Besides, Lleida had a robust irrigation system that Cervera did not have. The droughts in Cervera are therefore more "Mediterranean" like and thus it is consistent its presence in the Mediterranean Drought Index.'

This is not strange, since the usual clustering techniques use Euclidean distances to define clusters and they are appropriate for quantitative variables. Unfortunately, the methods section does not provide information on the distance used to measure the stations proximity.

We apologize for that, although it was included in the submitted manuscript denoted as Figure 2. Now the cluster analysis is explained more clearly and in more detail. Lines 213-223; 'We used the Ward's method in which the proximity between two clusters is the magnitude by which the summed squared in their joint cluster will be greater than the combined summed square in these two clusters SS12−(SS1+SS2) (Ward, 1963; Everitt et al., 2001). Then, the root of the square difference between co-ordinates of pair of objects is computed with its Euclidian distance. Finally, for each cluster within the hierarchical clustering, quantities called p-values are calculated via multiscale bootstrap resampling (1000 times). Bootstrapping techniques does not require assumptions such as normality in original data (Efron, 1979) and thus represents a suitable approach applied to the semiquantitative characteristics of drought indices (DI) derived from historical documents. . .'

In my view, the authors should repeat the clustering process but applying a technique appropriate to their data (semiquantitative and nonlinear indices with a short range 0-3)

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and should interpret the results much more carefully. To add credibility to the exercise, I suggest that they compute the SPI or SPEI indices for the 13 locations during the instrumental period and check and compare the results with those obtained with the historical indices. This would provide a certain idea of the consistency of the results.

We have now better justify the cluster technique applied. In addition, we have incorporated the validation section, including the calculation of the instrumental SPI and SPEI drought indices suggested by the reviewer. However, the validation between instrumental data and the Drought Indices derived from historical documents cannot be extended to the 13 cities due to the lack of overlapping periods. Most of the instrumental records in Spain, especially in small towns such as those studied here, begin in the second half of the 20th century. We believe that the high correlation found between the instrumental series of Barcelona and the Mediterranean Drought Index is already asserting the validity of our methodology to convert the rogation ceremonies into a continuous drought index.

Minor comments Language should be rechecked since there are several grammar errors. The authors should unify terminology (Lleida/Lerida; Girona/Gerona) The references to gray literature in Spanish should be eliminated or minimized.

Done.

#Anonymous reviewer 2. This study is very interesting and provides new and valuable data to the scientific knowledge on droughts in the northeast of Spain in the last centuries. The main contribution to the historical climatology of this region lies in the fact that the study assembles an important set of series of rogation ceremonies, including two new unpublished se- ries (Barbastro and Huesca). The study has potential to be published in Climate of the Past, however, in my opinion there are aspects of methodology and discussion that must be improved and completed in order to raise the overall quality of the article and achieve the quality standards of the journal.

Many thanks for the positive comments.

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Main remarks: 1. An important recommendation is about the presentation of the method and its limitations. Data of rogation ceremonies were converted into a “Drought Index” (DI) which was developed and applied in previous publications, as referred by the authors. However, the DI description is not totally correct when the authors simply say that “rogation data was transformed into quantitative monthly series” since the DI is, in fact, defined by an ordinal scale of intensity of droughts. Therefore, the study is based in a semi quantitative approach (DI series), which must be clearly stated in the methodology, as also the inherent limitations for the significance of the DI series should be more detailed and emphasized (in section 2, “Methods”).

We appreciate the suggestions, which we believe have been now clarify. As responded in the general response. We also clarify the nature of our data by performing an Empirical Cumulative Distribution Function. The derived drought indices can take values between 0 and 3 (see Fig. 2AB, included now in the manuscript), and thus can be considered as a continuous variable. In addition, as suggested by #Anonymous reviewer 1, we have now included a new paragraph in the manuscript showing the ‘validation’ of our data, including the new Figure 5, which we believe clearly shows the strength of rogation ceremonies as drought proxies.

We performed the cluster analysis to study meaningful groups of historical documents that share common characteristics. We agree with the reviewers that multiple cluster techniques will provide different results, but in this specific case we believe that the three clusters have spatial coherency (as commented in detail in the point by point response below).

We have now extended the description of the drought index limitations including the following suggested changes. Lines 371-380;‘Further limitations of converting qualitative information into quantitative data refer to the fact that, for instance, a drought index of level 2 does not necessarily imply a drought twice as intense as a drought index of level 1. This is an inherent limitation when dealing with historical documents as a climate proxy, and different approaches have been applied in the scientific literature

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(Vicente-Serrano and Cuadrat, 2007; Dominguez-Castro et al., 2008). In our paper, we follow the methodology proposed in the Millennium Project (European Commission, IP 017008) and demonstrated in Domínguez-Castro et al., (2012). To that extent, the ECDF helped understanding the nature of the historical documents when transformed into semiquantitative data which confirm that they can be treated as a continuous variable..'

However, the fact that the correlation of the overlapping period between the instrumental and the regional DIMED is very high and stable over time suggests that the rogations ceremonies can be considered as a drought indicator. In such a catholic society, similar droughts throughout the territory would trigger similar religious acts, which at the same time cost money. The authorities and the church would not perform an expensive rogation ceremony of level 3, unless drought is severe and the yearly harvest is in danger.

2. Another important weakness of the study is the total absence of information on the historical archives visited and basic description of sources gathered within the data collection. In text, I have found only a reference to the "Actas Capitulares" of the cathedrals. ThatâĂšs all? the single information provided on these important issues are the location and periods of the series (table I) which in my opinion is poor and quite insufficient to the readers and interested researchers. I suggest changing and complete this table or, preferably, add a new table with the recommended contents or even include a dedicated appendix.

We apologize for the absence of information on the historical archives that were visited. Now this information is included in the supplementary material Table S1.

3. In the methodology description the authors did not mention the completeness of the rogation records of the 13 collected series or even if there some possible gaps our periods with doubtful information from 1650 to 1899. Is it possible to estimate (approximately) the degree of temporal continuity of each series of rogation records? All

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uncertainties related with the study must be clearly stated. If the 13 series are complete permitting a suitable chronological analysis, please emphasize this fact, otherwise the readers may not be aware on the reliability of the data.

We appreciate this comment. While the temporal length of each site was presented in Table 1, we provide more detailed information in the introduction and in the method sections. Lines 162-164; 'The extension of the consulted documents (described in Table S1) ranges from 461 years of continues data in Girona, to 120 years in Lleida, with an average of 311 years of data on each station.

4. In the "Discussion" section some comments are missing about the apparent lack of coherence of cluster "Mountain" among the three defined drought patterns regions. As the authors pointed out, the correlations of DI within this group were weak or without statistical significance, but this evidence should be interpreted. What facts could explain this incoherency (or at least contribute to understand it). In my opinion these comments are relevant to support the consistency of the regional classification of drought series.

We have now extended the discussion part. Lines 459-466; 'In particular, the mountain areas show less vulnerability to drought compared to the other regions. This is mainly due to the fact, that mountainous regions experience less evapotranspiration, more snow accumulation and convective conditions that lead to a higher frequency of thunderstorms during the summertime. In addition, the productive system of the mountain areas is not only based on agriculture but also on animal husbandry, giving them an additional source for living in case of extreme drought. This might explain the lower coherence among stations within the DIMOU.'

5. In the "Results" section is included a detection of the extreme drought years in the northeast of Spain (3.3). Some aspects shown in figure 5 appear someway surprising, particularly when we compare the DI level occurred in quite closer cities in certain extreme drought years (see the example of Lleida and Cervera in 1775 and 1798) and

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some (apparently) contradictory results emerge. Since droughts are regional climatological events, not “local” phenomena, how can be explained such apparent spatial inconsistency? Some comments or plausible arguments should be added in Discussion section to avoid possible questions or doubts that, reasonably, may arise to the readers.

We appreciate the comments. We modified the corresponding text as follows: Lines 389-403; ‘In addition, the clusters might not only be collecting climatic information but also diverse agricultural practices or even species. For instance, Cervera and Lleida, sharing similar annual precipitation totals, belong to the Mediterranean and the Mountain Drought Indices respectively. Lleida is located in a valley with an artificial irrigation system since the Muslim period, which is fed by the river Segre (one of the largest tributaries to the Ebro river). The drought in the Pyrenees is connected with a shortage of water for the production of energy in the mills as well as to satisfy irrigated agriculture. However, the irrigation system itself allowed them to manage the resource and resist much longer. Therefore, only the most severe droughts, and even so in an attenuated form, are perceived in the city. Cervera, located in the mountains, in the so-called pre-littoral system and its foothills, has a different precipitation dynamic more sensitive to the arrival of humid air from the Mediterranean. Besides, Lleida had a robust irrigation system that Cervera did not have. The droughts in Cervera are therefore more "Mediterranean" like and thus it is consistent its presence in the Mediterranean Drought Index.

Minor comments: Line 129: “regional droughts” instead of regional drought”; Line 134: Consider replace “geological formations” by “geological units” or geological regions”; Table 1: add variables units (are totally absent); Cities names are not uniformized in the text, figures and tables (e.g. Lleida and Lerida, etc.)

Done.

Figure 2. The empirical cumulative distribution function (ECDF) used to describe a

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sample of observations for a given variable. Its value at a given point is equal to the proportion of observations from the sample that are less than or equal to that point. ECDF performed for the local drought indices (A) and the regional drought indices (B).

Figure 5. A) 30y moving correlation between DIMED and the instrumental computed SPI and SPEI. B) Same but 50y moving correlations. C) Correlation (Spearman) between DIMED and SPIMAY_4 for the full period (1787-1899). D) Correlation (Spearman) between DIMED and SPEIMAY_4 for the full period (1787-1899).

Please also note the supplement to this comment:
https://www.clim-past-discuss.net/cp-2018-67/cp-2018-67-AC1-supplement.zip

Interactive comment on Clim. Past Discuss., https://doi.org/10.5194/cp-2018-67, 2018.

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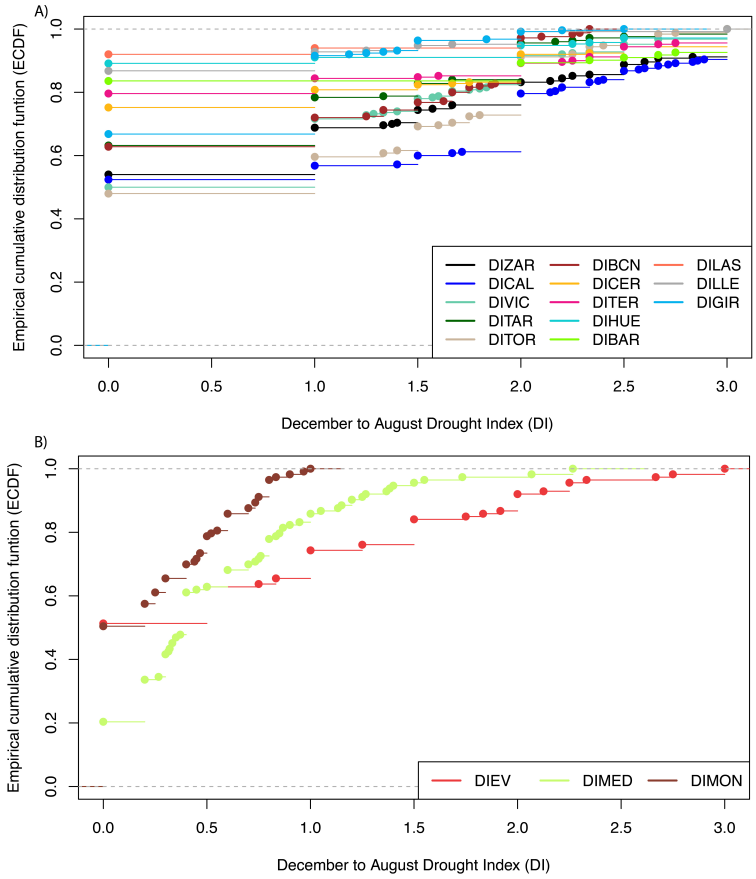

Fig. 1.

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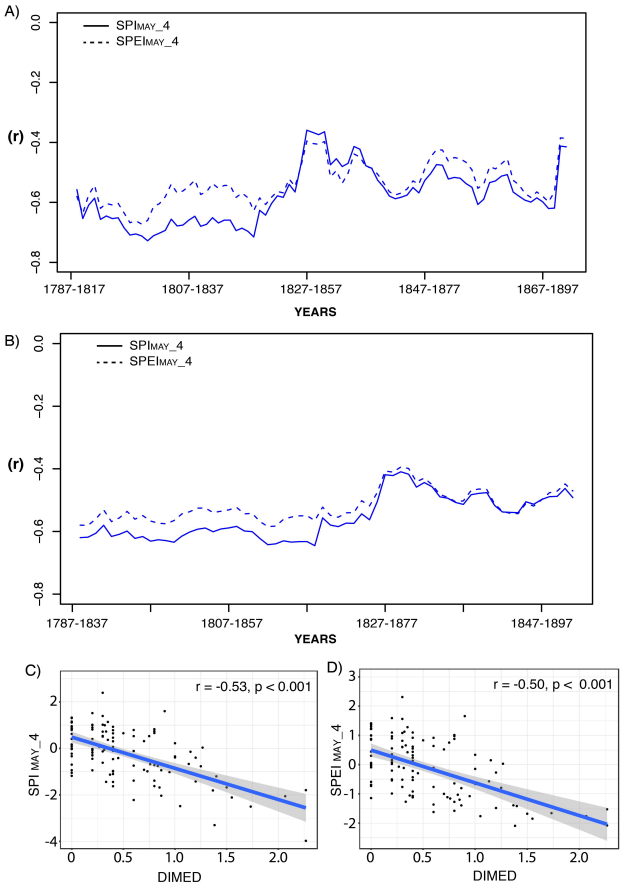

Fig. 2.

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