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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "High-spatial resolution probability maps of drought duration and magnitude across Spain" *by* Fernando Domínguez-Castro et al.

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Anonymous Referee #1 The topic of this paper is very actual and important taking into account recent extreme climate events and what we will face in near future. The authors have presented probabilities of extreme drought events in terms of drought duration and magnitude. They compared two the most used drought indices (SPI and SPEI) at 4 time scales and high spatial resolution by applying extreme value theory. In order to increase readability and relevance of the paper some points need to be addressed. Many thanks; we appreciate your positive comment and recommendations.

Some parts of the text are hard to understand so I would recommend English check

before final publication. Please use term "percentile" instead of "centile". Overuse of the adverb "Nevertheless". The text has been polished by a professional English speaker. We have replaced "centile" by "percentile" in the whole manuscript. We have also reduced the use of "Nevertheless" in the text.

The Abstract should be rewritten as well as the Section "Data and methods" since it is not clear in every step what is done on what data and it would not be understandable to wider audience. All these sections have been revised carefully and we believe that the flow of the text and the readiability of these sections are highly improved.

Through the selection of the appropriate threshold you observed percentiles from 0th to 95th. Why haven't you take values greater than e.g. 40th or 50th percentile since you are studying extremes? Then you would have less figures and they would be more visible. Figures are hardly visible (Supplement ones even less), especially if they are printed in black and white. Lines and dots should be thicker. We completely understand the concerns of the reviewer. However, recalling that this study provides the first comprehensive assessment of drought probability in the whole Spain, we are keen to evaluate all the percentiles to understand better the studied variables. In accordance with the reviewer's comment, we have improved the resolution of the figures to make their readiability much easier.

Page 1 L10 – "-for the first time-" should be removed. Make unique terminology – drought severity > drought magnitude. It is not the same. Amended.

L14 ". . .implying that drought event is attained only when the index values are lower than zero." It is not "implied". It is according to index definition. Or I didn't understand the sentence well. We have rewritten the sentence. However, it is noteworthy indicating that there are no global standard criteria to define drought events. McKee et al. (1993) adopted a threshold of SPI lower than -1 or -0.8 to select drought events. In this study, a drought index value below zero was defined. This threshold allows for detecting all drought events, regardless of duration and severity. Our motivation of this selection is

explained in the new version of the text, as: “We used an arbitrarily-defined threshold (equal to zero) to define drought events. Although this threshold allows for inclusion of less severe drought events, it can secure a sufficient sampling size to conduct the probabilistic analysis. Importantly, the retention of drought events in this manner will not bias the obtained results, given that high values of the series will be retained following the peak-over-threshold approach”.

L15 “drought severity and magnitude series” > “drought duration and magnitude series” We have changed.

L16 “evaluating different three-parametric distributions” – in the text you are mentioning only one distribution, have you tested some more? We have deleted this sentence from the abstract to avoid ambiguity. We represent the generalized logistic, generalized extreme value, generalized Pareto, generalized normal and Pearson type III, in Figures 1,2 and supplementary Figures 1-14. However, these figures show that Generalized Pareto is clearly the distribution with the best fit. The outperformance of GP distribution has already been confirmed in many earlier studies. In specific, many studies demonstrate that the probability distribution of a POT series with random occurrence times fits well with GP distribution (see for example, Hosking et al., 1987; Pham et al., 2014; Wang, 1991). This is why we have not analyzed the findings of other statistical distributions. Hosking, J. R. M. and Wallis, J. R..: Parameter and quantile estimation for the generalized pareto distribution, Technometrics, 29(3), 339–349, doi:10.1080/00401706.1987.10488243, 1987 Pham, H. X., Asaad, Y. and Melville, B.: Statistical properties of partial duration series: Case study of North Island, New Zealand, J. Hydrol. Eng., 19(4), 807–815, doi:10.1061/(ASCE)HE.1943-5584.0000841, 2014. Wang, Q. J.: The POT model described by the generalized Pareto distribution with Poisson arrival rate, J. Hydrol., 129(1–4), 263–280, doi:10.1016/0022-1694(91)90054-L, 1991.

L29 What are the “large legislation practices”? The most important legislation practice in Spain is the Special Drought Plans. There is one Plan per hydrological basin. In

2018, the new plans were approved, which substitute the earlier plans of 2007. We have included these Plans as examples in the text . “In addition to the different monitoring systems for hydrological drought conditions (Maia and Vicente-Serrano, 2017), there are national legislation practices that aim to improve drought adaptation strategies and practices, such as Special Droughts Plans”

Page 2 L10-L14 If the stated studies “developed drought-related probability maps for Spain” how they “did not account for the different drought hazard probability”? I understand the point you want to make, but the text should be reformulated. We have rewritten the text, as follows: “In Spain, several studies have developed dry spells probability maps (e.g. Lana et al., 2006; Martin-Vide and Gomez, 1999; Pérez-Sánchez and Senent-Aparicio, 2018). However, given that the probability of occurrence of dry spells is higher in arid regions than in humid regions, these studies did not account for the different drought hazard probability across Spain. It is well-recognized that the frequency and duration of dry spells are closely driven by the climatology of the studied area. As such, it can be expected that a simple map of climate aridity in Spain can show similar spatial patterns to those of dry spell probability”. Lana, X., Martínez, M. D., Burgueño, A., Serra, C., Martín-Vide, J. and Gómez, L.: Distributions of long dry spells in the Iberian Peninsula, years 1951-1990, Int. J. Climatol., 26(14), 1999–2021, doi:10.1002/joc.1354, 2006. Martin-Vide, J. and Gomez, L.: Regionalization of peninsular Spain based on the length of dry spells, Int. J. Climatol., 19(5), 537–555, 1999. Pérez-Sánchez, J. and Senent-Aparicio, J.: Analysis of meteorological droughts and dry spells in semiarid regions: a comparative analysis of probability distribution functions in the Segura Basin (SE Spain), Theor. Appl. Climatol., 133(3–4), 1061–1074, doi:10.1007/s00704-017-2239-x, 2018

L20 What do you mean by “normalizing data of climatic variables for common periods”? > Suggestion “climate data standardization over standard climatological periods” We have followed the suggestion, as: “This highlights the importance of data standardization to make drought characteristics (e.g. duration, intensity, severity) comparable

among regions with different climatic conditions".

L23 There are various drought indices including ones that do not account for the climatology of the location that is observed, as you explained in part L14-20. You should specify the group of drought indices you are talking about. Amended. We have include some examples "e.g. Standardized Precipitation Index, Standardized Precipitation Evapotranspiration Index, Palmer Drought Severity Index, Self-calibrated Palmer Drought Severity Index"

L25-26 Sentence "Taken together. . .." should be reformulated. We have reformulated as: "Overall, based on these drought indices, it is possible to map the probability of occurrence of drought duration and magnitude at a detailed spatial resolution."

Page 3 L6 "Unfortunately, this aspect has receives less attention in the literature." Is this your opinion? Can you somehow confirm this statement? If not, it should be omitted. We have omitted this statement.

L19 Datasets cover the whole Spain. How many points are in the grid you considered? We have 1115 * 834 pixels, in which 412178 pixels have data, while other pixels correspond to the Mediterranean Sea and Atlantic Ocean. We have included this information in the text, as: ". . .developed a high-resolution spatial (1.21 km2) and temporal (weekly) drought dataset for Spain (412178 pixels)."

L19- 20 What is the source of the meteorological parameters? The raw data were provided by the National Spanish Meteorological Services (AEMET). After a careful check of the quality and homogeneity, the raw data of each climatic variable was interpolated to create a gridded dataset for the whole Spain. This has been clarified in the text, as: "Based on gridded datasets of maximum and minimum air temperatures (1304 observatories), precipitation (2269 observatories), wind speed (82 observatories), relative humidity (179 observatories) and sunshine duration (112 observatories), Vicente-Serrano et al. (2017) developed. . ."

L21 Have you calculated the indices or are the datasets for the indices downloaded from the website you provided? Vicente-Serrano et al. (2017) developed the indices. We have rewritten the text to clarify this point. Vicente-Serrano, S. M., Tomas-Burguera, M., Beguería, S., Reig, F., Latorre, B., Peña-Gallardo, M., Luna, M. Y., Morata, A. and González-Hidalgo, J. C.: A High Resolution Dataset of Drought Indices for Spain, Data, 2(3), 22, doi:10.3390/data2030022, 2017.

L23 What is "normalization of the climatic balance"? We have considered this comment, as: "SPEI is based on normalization of the difference between precipitation and atmospheric evaporative demand"

L24 Which method have you used for PET calculation? The method to compute ET0 was the reference FAO-56 Penman-Monteith (Allen et al., 1998). R.G. Allen, L.S. Pereira, D. Raes Crop evapotranspirationâĂŤguidelines for computing crop water requirements FAO Irrigation and drainage paper 56 (1998)

L28 Chosen timescales include agricultural drought as well, and agriculture is very important sector. It should be included. It should be stated here that the indices include wet conditions as well, and the indices values below 0 signify drought condition. You mentioned it in the Abstract but not in the text. For which time period have you calculated distribution parameters for indices calculation? Agricultural droughts are very important in Spain. The damages to agricultural are generally related to 3-, 6- month time scales (Pacoa et al., 2017; Peña-Gallardo et al., 2019). We believe that the readers of NHESS are aware of the the SPI and SPEI. As such, we believe that it is not necessary to indicate that each index has positive values that reveal wet conditions. Our decision to define drought events using a SPEI/SPI threshold of zero is clearly explained: "We used an arbitrarily-defined threshold (equal to zero) to define drought events. Although this threshold allows for inclusion of less severe drought events, it can secure a sufficient sampling size to conduct the probabilistic analysis. Importantly, the retention of drought events in this manner will not bias the obtained results, given that high values of the series will be retained following the peak-over-threshold approach".

The distribution parameters for the indices are calculated for the whole period 1961-2014. Pascoa P, Gouveia CM, Russo A, Trigo RM (2017) The role of drought on wheat yield interannual variability in the Iberian Peninsula from 1929 to 2014. Int J Biometeorol 61:439–451. Peña-Gallardo, M., Vicente-Serrano, S. M., Domínguez-Castro, F., and Beguería, S.: The impact of drought on the productivity of two rainfed crops in Spain, Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2019-1, in review, 2019

"Page 4 L1-10 I think this part is unnecessary and brings a bit of confusion in the paper. According to the indices definition, drought event is when the indices values are below 0. For each drought event you calculated its magnitude and duration and then extracted extreme ones using POT. There was no need to introduce run theory. We have deleted the reference to run theory. But we consider appropriate the justification of the election of 0 as a threshold. Probably some readers were familiarized with other thresholds as -0.8 or -1 to define drought periods

L13 I am curious how you did the integration. I don't have access to Dracup paper, so if you could be more specific on this. L15 "drought duration was calculated for the consecutive weeks. . ." > "drought duration was calculated as number of consecutive weeks. . ." It is a simple integration of the values below 0 as you can see in figure 1 from López-Moreno et al. (2009). López-Moreno J.I, Vicente-Serrano S.M., Beguería S., García-Ruiz J.M., Portela M.M., Almeida A.B. Dam effects on drought magnitude and duration in a transboundary basin: The lower River Tagus, Spain and Portugal. Water resources research 45, W02405.

L19 Stationarity is referred to series of drought magnitude and duration, right? Definitiely.

L26-30 In the abstract you are mentioning "evaluating different three-parametric distributions". Have you tested some other distributions beside GP? On the Figure 1 are presented L moment diagrams for different distributions, but in the text there are no

explanations regarding them. We have deleted this sentence from the abstract pleas se the comment to the P1. L16.

Page 5 L3-4 Repetition of the Page 4 L26-30 Thank, we have delete this sentence to avoid repetitions.

L6-L13 This part should be rewritten and be one paragraph. The first sentence "Hosking (1990). . .." Is hanging and it is connected to the sentence in L2 of the previous paragraph but I cannot see its point in the whole text? The whole section 2.3 has been rewritten and the readiability has improved.

Sentences from L8 till L12 refer to the same thing: you plotted L-moment diagrams and applied Anderson-Darling test to obtain and test POT series, fitting to GP distribution, for different x0 thresholds; am I right? Yes you are.

L17 "t years" or "T years"? Amended.

L19 What is "original sample" in this case? It refers to drought duration and magnitude over the whole study period (1961-2014).

L14-L21 There should be one paragraph referring to maximum duration and magnitude. We have included a reference to the maximum duration and magnitude.

Page 6 L1 Formula is not explained, i.e. elements of formula are not defined. We have included a description of all symbols included in this equation.

L9 "Nevertheless... 1-month timescale can be different considering other drought timescales." It can be, but is it in your study? No, it is not. We have omitted this sentence because it is already stated in L 12. Figs S1-S14 suggest similar patterns for other timescales as well as for the drought duration and magnitude series obtained using the SPI.

L4-11 Is there any specific reason why you have chosen to present SPEI1 for duration and SPEI12 for magnitude? We attempted only to give an example of short and

long timescale. Results corresponding to all timescales are already presented in the supplementary material.

L13 There are too many supplementary figures regarding this part. Can they be reduced and just described in the text. There are no significant differences between them (I think, the dots on the Figures are barely visible on some panels. . .is there any for 95th percentile?). We prefer to provide all the information in the supplementary material. As NHESS is an online journal, all readers can easily access the supplementary material. Moreover, the limitation of the journal to the supplementary material is 50MB and we are very far from this limit.

L15 Have you done Anderson-Darling statistic for other distributions? What are the other distributions that you have tested? We have not considered this statistic for other distributions. As illustrated in Figs. 1,2, and S1-S14, our results confirm that the best fit is recorded with GP distribution. This finding concurs well with what earlier studies suggest (Hosking et al., 1987; Pham et al., 2014; Wang, 1991). Hosking, J. R. M. and Wallis, J. R..: Parameter and quantile estimation for the generalized pareto distribution, Technometrics, 29(3), 339–349, doi:10.1080/00401706.1987.10488243, 1987 Pham, H. X., Asaad, Y. and Melville, B.: Statistical properties of partial duration series: Case study of North Island, New Zealand, J. Hydrol. Eng., 19(4), 807–815, doi:10.1061/(ASCE)HE.1943-5584.0000841, 2014. Wang, Q. J.: The POT model described by the generalized Pareto distribution with Poisson arrival rate, J. Hydrol., 129(1–4), 263–280, doi:10.1016/0022-1694(91)90054-L, 1991.

L20-21 “Notably. . ..” This sentence refers to 1-month scale or general? To the 1-month time scale, we have revised this statement to make it clear, as : “The only exceptions are found for the duration series obtained at 1-month time scale using both SPI and SPEI, but considering thresholds higher than 80th percentile. The total percentage of these series is almost close to 100%”.

L26 Could you please say something more on Fig 3? Does Fig 3 unify duration and

magnitude? Scales on panels are different (even for the same percentile) so they are hardly comparable. Figure 3 is the number of cases, so it is the same for duration and magnitude. We have included a sentence explaining the main result of the figure. “Figure 3 shows the number of drought events corresponding to the different percentiles and timescales (i.e. 1-, 3-, 6-, and 12-month). It can be noted that the number of events using the 90th and 95th percentile thresholds is very low for all timescales. This low number of events is statistically insufficient for reliable estimation of L-moment and GP parameters (Table 2)”.

L28 What did you do in the cases when you could not calculate distribution parameters? Is this 99% referring to percent of series for both indices, magnitude and duration, all time scales and all grid points? Yes, in less than 1% of all series, we were not able to calculate the parameters. In such cases, we excluded these pixels (series) from subsequent analyses.

L29 “A comparison of the observations and estimations. . .” where we can see this? This can be seen in Figure 4. However, we have deleted this sentence to avoid any misunderstanding. Page 7

L4 “Similar results . . ..” Does it mean that previous sentences are related to other two metrics? We have deleted this statement.

L6 “Again . . . at the pixel scale. . .” - what else was compared on pixel scale? As I understood, previous paragraph was on maximum duration/magnitude over the whole grid. There is an error. The “Again” is not correct. We have corrected as: “The comparisons were made at the pixel scale. . .”

L7 Have you plotted cdfs for every grid point and then chosen the representative example? Why this grid point? Could you put some mark on this point on Fig 6. Do you have any idea why there is smaller correlation in some locations, are there any specific geographical characteristics that influence the results (e.g. in NW for SPI3 duration, Fig.6)? Indeed, it is extremely difficult to plot cdfs for a total number of 412.178 pixels.

Rather, we randomly selected one pixel. We clarified the coordinates of this grid (L21). It is quite difficult to mark this point in Figure 6, as it will mask hundreds of pixels. We cannot see a clear geographical pattern representing locations with small correlation. As such, it is difficult to provide an explanation of this pattern. Probably, it can be linked to the generation of the gridded SPI and SPEI values.

L18-L21 What the differences mean? In general, what these figures are showing, what you can conclude from them? It is notable that κ changes the sign between 3 and 6 month timescale for all cases (SPI/SPEI and duration/magnitude), do you have idea why? We have included a paragraph describing and interpreting both figures, as follows. "Figures 7 and 8 illustrate the spatial distribution of GP parameters calculated for drought duration series obtained using the SPI and SPEI, respectively. The GP parameters show very similar distributions for the SPI and SPEI. However, there are considerable spatial variations in the distribution of these parameters as a function of the drought timescale, with higher values of the location (Xo) and scale (α) parameters for longer time scales. This can be explained by the increase in drought duration at longer time scales. The shape (k) parameter shows similar range values for all time scales. It is difficult to interpret the geographical distribution of shape (k) due to there is large uncertainty involved in estimating this parameter (Rosbjerg et al., 1992). As illustrated in Supplementary Figure S15 and S16, all parameters show similar spatial patterns for the drought magnitude series". Rosbjerg, D., Madsen, H., Rasmussen, P.F.: Prediction in partialduration series with generalized Pareto-distributed exceedances, Water Resources Research, 28(11): 3001 – 3010, 1992

L22 "We mapped drought probability. . .. using the parameter maps and Eq.3" – How did you do this, using some GIS software? R was used to produce this figure. It is a publicly free software (https://cran.r-project.org/bin/windows/base/).

L31 "southeast" or "southwest"? This is an unexpected error that we corrected in the new version of the manuscript.

Page 8 Supplementary Fig 17, 18 - What are "SPI/SPEI units"? Both indices are normalized using a probability distribution function, so that values of SPI or SPEI are actually seen as standard deviations from the median. We have changed to z-units.

L31 You mention "climatic balance" again. Climate balance is based on the balance between various components of climate system. I doubt you are referring to them all, so this terminology is not correct. We have rewritten as: "i.e. precipitation or difference between precipitation and atmospheric evaporative demand".

Page 9 L6 "This difficulty is also enhanced by our findings on the spatial differences in the drought probability in response to the selected drought index." But in Page 7/8 you say "Drought probability maps using the SPI show spatial patterns similar to those observed by means of the SPEI". So, are there significant spatial differences in the drought probability comparing two indices? We have reformulated the sentence of page 7/8 to stress the differences between the SPI and SPEI. "The aim was to assess whether there are noticeable spatial differences in the obtained drought hazard probabilities, as a function of the selected index and/or timescale".

L21 "As such, the degree of vulnerability can vary according to drought timescale" – I would add "drought timescale and region." We have included.

Technical corrections Please make unique way of representation in tables and figures: order of SPI and SPEI as well as "duration" and "magnitude". Page 1 L26 Add "e.g." in the brackets since you stated only two articles published in 2018. L30 "practices to drought events" – should it be "practices during drought events"? Page 2 L10 "several works" > "several studies" L17-18 "wet conditions" > "moisture conditions" "km2" > "km2" Page 4 L3 "varying" > "various" L11 ". . .drought event as that event with a period. . ." > ". . . drought event as period. . ." Page 5 L2 "(Hosking, 1990)" > "Hosking (1990)" L4 "world regions" > "regions of the world" Page 7 L9 "low agreement" > "lower agreement" (because in preceding sentence you said "very good agreement" for all; not to be contradicted) L23 "predicted" > "estimated" L28 "12-month" > "12-months"

L31 “>180 months” > “>180 weeks” Page 8 L10 “Standardized precipitation Index” > “Standardized Precipitation Index” L19 “was made to make balance” > “was to make balance” Page 12 L3 & L7 Check the references (names of the authors) In Table 1, “SPEI”, the “I” went to the second row.

Many thanks for all these technical corrections. We have modified the text following your recommendations.

Figure 3 Both lower and upper panels have the same name “SPEI” We appreciate this comment. The figure was wrong, we have corrected in the new version of the manuscript.

Figure 6 There is number “40” on panels SPI 1, 3, 6 for duration. We have deleted the “40”.

Figure 11 Axis labels “duracion” > “duration” Amended.

Supplementary Fig 19 – Figure caption is for duration Amended.

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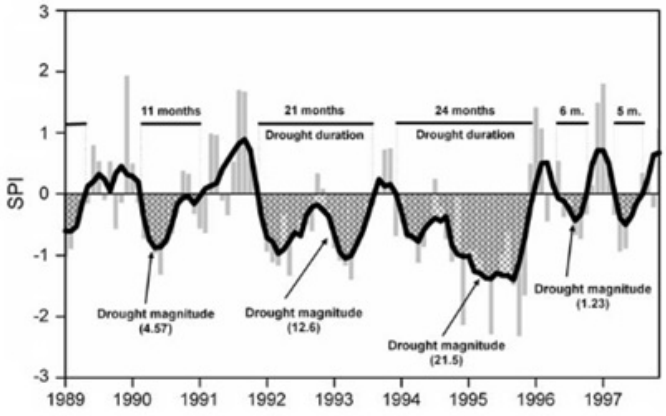

Figure 3. Example of the smoothing procedure employed for standardized precipitation index (SPI) series and calculation of drought magnitude and duration.

Fig. 1.