

**Interactive comment on “Rankings of extreme and widespread dry and wet events in the Iberian Peninsula between 1901–2016” by Margarida L. R. Liberato *et al.***

**Referee comments by Anonymous Referee #1**

This study describes the main dry and humid events that have affected the Iberian Peninsula from 1901 to 2016. The research topic addressed is relevant nevertheless, the study is principally descriptive. This is not a limitation per se, but further discussion should be necessary to justify the relevance and novelty of this study in comparison to the several studies (some of them very recent) analysing droughts from different perspectives in the Iberian Peninsula.

Reply: We thank the reviewer for the constructive comments, which will hopefully contribute to improving the revised manuscript. Our detailed responses can be found below.

We thought the main objectives and motivations underpinning this manuscript were clear from the beginning. As we wrote in the abstract (lines 12-13): “Here, a method for ranking regional extremes of persistent, widespread drought and wet events is presented, considering different time scales”. We also wrote in the introduction (lines 100-105):

“In summary the main goals of this paper are to:

- (i) present a tool which allows identifying regional extremes of persistent, widespread dry and wet periods, at different time scales;
- (ii) build a comprehensive dataset of rankings of the most extreme, prolonged, widespread drought and wet periods on Iberia (...)”

In this regard, this manuscript **does not aim at:**

- 1) analysing droughts from different perspectives in the Iberian Peninsula;
- 2) comparing or assess extremes (wet and dry) using different indices;
- 3) evaluating how extreme an event (wet or dry) using the impact perspective;
- 4) characterizing extremes from the impact perspective;
- 5) assessing the different mechanisms behind de extreme events;
- 6) assessing the climate change signal or the dependence of these extremes (wet or dry) on the different variability modes.

The authors have participated in the last 2 decades in more than 30 works that cover those different aspects of droughts in Iberia and elsewhere, but those were clearly not the focus in the current analysis. We would like simple to contribute with a simple, but yet robust methodology that is useful to rank wet and dry events, considering both their magnitude and spatial extent.

We would like to stress that **we have the purpose of ranking both wet and dry (and not to detail the case of droughts) events**. The ranking methodology is here applied to both type of episodes (wet and dry), highlighting the extreme or severe character of their occurrence.

We agree that all these are very relevant and interesting research questions, and these are some of the research questions that motivated us to identify that there is not a ranking of extreme and widespread dry and wet events, yet. However, the characterization and evaluation of impacts for both extreme (wet and dry) episodes will utterly enlarge significantly the present

manuscript. This would pose as a disadvantage in terms of the focus of the article, which we think would be much disperse.

Therefore, we will include changes that will clarify and explain better the motivation and scope of the paper. We will also highlight the relevance and novelty of this study, which is presenting a methodology for building rankings of extreme and widespread dry and wet events, for several timescales, whatever indices datasets are used (in this case we used SPEI).

In addition, there are some methodological issues that should be considered to remove some interpretations of the obtained results.

There are also some data issues and recommendations to improve the manuscript. I would suggest a major revision of this manuscript.

Reply: We thank the reviewer for these comments. A detailed response to all the reviewer's comments will follow.

**Comments:**

42. typo: Spatial extend

REPLY: The typo will be corrected.

44. I would also mention environmental or ecologic droughts (e.g. <https://doi.org/10.1016/j.earscirev.2019.102953>)

REPLY: We will include the reference to the recent concept of environmental or ecologic droughts, as follows (line 54):

*"In recent years, a special focus was put in environmental or ecologic droughts when considering long and widespread dry events with strong impacts that may induce changes in natural and managed ecosystems (Crausbay et al., 2017, Vicente Serrano et al., 2020)"*

- Crausbay et al., 2017, Defining Ecological Drought for the Twenty-First Century, Bull. Amer. Meteor. Soc., 98 (12): 2543–2550. <https://doi.org/10.1175/BAMS-D-16-0292.1>)
- Vicente Serrano et al., 2020 A review of environmental droughts: Increased risk under global warming? Earth-Science Reviews, 201, 102953 (<https://doi.org/10.1016/j.earscirev.2019.102953>)

44-54. I do not think necessary here to describe in depth these drought types.

REPLY: We appreciate the reviewer's concern. However, the mentioning of the different types of droughts has the goal of highlighting the different time-scales of the dry extreme events and the need of using a multiscalar index, such as SPEI. Therefore, we opt by reducing detail, but without removing it completely.

58. The PDSI is not recent. I suggest to cite a study that reviews drought indices (e.g. <https://doi.org/10.1175/1520-0477-83.8.1149>, <https://doi.org/10.1007/s40641-018-0098-x>).

REPLY: We agree with the reviewer and the suggested comment and references will be added to the manuscript.

63-68. I would remove this criticism of the PDSI. I do not it is needed here.

REPLY: We agree with the reviewer and the manuscript will be changed accordingly.

85. This is not a water balance model. The SPEI is not intended to be soil moisture metric.

REPLY: We understand the reviewer's comment and therefore we change the sentence as follows:

“water balance is reflected on SPEI computation by the inclusion of ...”

93-99. I would suggest to revise recent literature on this topic also in the Iberian Peninsula (<https://doi.org/10.1002/joc.6719>, <https://doi.org/10.1007/s11600-018-0138-x>, <https://doi.org/10.1111/nyas.14365>, <https://doi.org/10.1002/joc.6126>).

REPLY: We thank the reviewer for the suggestions and the additional literature will be included. The manuscript will be changed accordingly:

*“The characterization of wet and dry periods in the IP is extremely important as the region is frequently affected by extreme dry and wet events (González-Hidalgo et al., 2018; Domínguez-Castro et al., 2019; Vicente-Serrano et al. 2020) and consequently by their impacts on several systems (Liberato et al., 2017; Ribeiro et al., 2018, 2019) (...)”*

- Domínguez-Castro, F, Vicente-Serrano, SM, Tomás-Burguera, M, et al. High spatial resolution climatology of drought events for Spain: 1961–2014. *Int J Climatol.* 2019; 39: 5046– 5062. <https://doi.org/10.1002/joc.6126>
- González-Hidalgo, J.C., Vicente-Serrano, S.M., Peña-Angulo, D. et al. High-resolution spatio-temporal analyses of drought episodes in the western Mediterranean basin (Spanish mainland, Iberian Peninsula). *Acta Geophys.* **66**, 381–392 (2018). <https://doi.org/10.1007/s11600-018-0138-x>
- Liberato M. L. R., Ramos A. M., Gouveia C. M., Sousa P., Russo A., Trigo R.M., Santo F.E. (2017) Exceptionally extreme drought in Madeira Archipelago in 2012: Vegetation impacts and driving conditions. *Agricultural and Forest Meteorology*, doi: 10.1016/j.agrformet.2016.08.010
- Ribeiro, A. F. S., Russo, A., Gouveia, C. M., Páscoa, P., and Pires, C. A. L. (2019) [Probabilistic modelling of the dependence between rainfed crops and drought hazard](https://doi.org/10.5194/nhess-19-2795-2019). *Nat. Hazards Earth Syst. Sci.*, 19, 2795–2809, <https://doi.org/10.5194/nhess-19-2795-2019>

- Vicente-Serrano, SM, Domínguez-Castro, F, Murphy, C, *et al.* Long-term variability and trends in meteorological droughts in Western Europe (1851–2018). *Int J Climatol.* 2020; 1– 28. <https://doi.org/10.1002/joc.6719>

115. Nevertheless, the relevant issue is the number of stations used in the Iberian Peninsula. This is very relevant in this study. This is very relevant in this study since this may affect the obtained results since few interpolated stations may filter too much the spatial variance of the specific drought episodes.

REPLY: We acknowledge the reviewer’s concern. However, we would like to point out that the CRU dataset derives from thousands of stations scattered non randomly across the Earth, with much higher densities at mid-latitudes than in the tropics or the Arctic. Although, in terms of temporal bias, the CRU dataset logically contains many fewer observations in the early part of its record, this happens mostly in the tropical and Arctic regions (Macias-Fauria *et al.*, 2014), thus not affecting so much the more covered mid-latitude regions. Despite the smaller number of meteorological stations used to obtain the data in the first half of the 20th century when compared to the remaining years, Harris and coauthors (Harris *et al.*, 2013) show that their precipitation and temperature time series have a high correlation value with other datasets (Harris *et al.*, 2013). Macias-Fauria and coauthors (2014) show that for global studies the analyses should be undertaken using data after 1950s. However, the analysis of the present work is restricted to the IP region which includes a relatively homogeneous number of stations. Additional information about the number of stations for the considered variables in several years along the 20th century and also the methods used for interpolation and the representativeness of the available data is also provided in New *et al.* (2000) and Mitchell and Jones (2005). According to these authors the dataset is useful for a variety of climatic applications including hydrological modelling, climate change scenarios, and evaluation of regional climate models. Moreover, this database has been previously used by the authors (Russo *et al.*, 2015; Páscoa *et al.*, 2017), which have obtained good results in the IP, including for the earlier years (Páscoa *et al.*, 2017).

- Harris I., P. D. Jones, T. J. Osborn, and D. H. Lister, “Updated high-resolution grids of monthly climatic observations—the CRU TS3.10 Dataset,” *International Journal of Climatology*, vol. 34, no. 3, pp. 623–642, 2013.
- Macias-Fauria M., A. W. R. Seddon, D. Benz, P. R. Long, and K. Willis, “Spatiotemporal patterns of warming,” *Nature Climate Change*, vol. 4, no. 10, pp. 845-846, 2014.
- Mitchell T. D. and P. D. Jones, “An improved method of constructing a database of monthly climate observations and associated high-resolution grids,” *International Journal of Climatology*, vol. 25, no. 6, pp. 693–712, 2005.
- New M., M. Hulme, and P. Jones, “Representing Twentieth-Century SpaceTime Climate Variability. Part II: Development of,” *Monthly Grids of Terrestrial Surface Climate. J. Climate*, vol. 13, Article ID 190196, pp. 2217–2238, 2000.
- Páscoa P., C. M. Gouveia, A. Russo, and R. M. Trigo, “The role of drought on wheat yield interannual variability in the Iberian Peninsula from 1929 to 2012,” *International Journal of Biometeorology*, vol. 61, no. 3, pp. 439–451, 2017.
- Russo A. C., C. M. Gouveia, R. M. Trigo, M. L. Liberato, and C. C. DaCamara, “The influence of circulation weather patterns at different spatial scales on drought variability in the Iberian Peninsula,” *Frontiers in Environmental Science*, vol. 3, 2015.

Nevertheless, a sentence to highlight that the data on the first part of the XX century should be analysed with care will be added.

117. I wonder on the goodness of the VPD data for the first decades of the XXth century.

REPLY: We understand the reviewer's concern however we did not use VPD data. Comments about the quality of CRU dataset used on this work are already presented on previous comment.

132-146. There are strong uncertainties related to the calculation of the evaporative demand prior 1960s. This explains that some drought datasets based on the AED start in the decade of 1960 (<https://doi.org/10.3390/data2030022>). I am not convinced by the arguments provided to justify the use of the CRU dataset for the long-term, mostly for the atmospheric demand, at least in Spain few of the data necessary to calculate the AED with the FAO-56 method is not available. If author's main focus is the long term, I would recommend focusing only on precipitation data and the SPI. This would reduce uncertainty since CRU precipitation data shows good capacity to reproduce long-term precipitation variability in the region (<https://doi.org/10.1088/1748-9326/ab9c4f>).

REPLY: This comment is in line with the two previous. We agree with the reviewer that there are larger uncertainties present when using data prior than the 1960's. As highlighted on the previous comments, this was noted and will be highlighted in the text.

Nevertheless, we would like to point that the potential evapotranspiration used was extracted from CRU, which was calculated based on Penman-Monteith equation. This method is considered as the standard procedure for computing PET by several international institutions such as the Food and Agriculture Organization of the United Nations (FAO), the International Commission on Irrigation and Drainage (ICID), or the American Society of Civil Engineers (ASCE).

Moreover, we again would like to stress that this database has been previously used by the authors (Russo et al., 2015; Páscoa et al., 2017), which have obtained good results in the IP, including for the earlier years (Páscoa et al., 2017).

183-185. Repeated above.

REPLY: We agree with the reviewer. The sentence will be changed in order to avoid repetitions:

*“Here, SPEI was applied with the main purpose to identify the major extensive and/or extreme droughts which affected the IP, while illustrating the relevance of the method.”*

166. I suggest restricting the analysis to time scales below 12 months. The autoregressive character of SPEI and SPI affect the identification of the drought events and the possible trends (e.g., <https://doi.org/10.1002/joc.6350>, <https://doi.org/10.1175/JCLI-D15-0590.1>, <https://doi.org/10.1016/j.scitotenv.2020.140094>).

REPLY: We agree with the reviewer that one must be aware of the autoregressive character of SPEI and SPI. However, we would like to stress that in this work we only want to present a methodology to rank extreme wet and dry events, that is, we want to present a tool which allows

to compare extremes, taking into account both the intensity and the area affected. The reviewer is correct when highlighting that timescales higher than 12 months must be analysed cautiously. This is one of the important results of this work: by jointly comparing the rankings of extreme events (both wet and dry) among different timescales more information may be obtained on the real extremeness character of the events. Therefore, a sentence will be included in the manuscript pointing the autoregressive character of SPI and SPEI and reinforcing the need to look the results carefully.

*“It should be noted that due to the autoregressive character of SPEI (or SPI), results obtained for larger time-scales (18 and 24 months) should be looked very carefully.”*

Fig. 2 Most of the events identified are recorded in the decades of 2000 and 2005. I would ask if AED uncertainties may be biasing this issue. Droughts based on precipitation data do not show so important trends (<https://doi.org/10.1002/joc.6719>). Also SPEI data based on high quality data in Spain does not show so important trend (<https://doi.org/10.1002/joc.6126>).

REPLY: We thank the reviewer for the comment. In fact, we are aware about the impact of the AED uncertainties on trends for the recent years and we agree that we should include a sentence enriching the discussion. Furthermore, we would like to recall the reviewer that this paper is not studying droughts, nor its trends. We are presenting a methodology which allows to categorize, to rank, to hierarchize, to compare different extreme events (both dry and wet), including the affected area. Individual, recent, extreme wet/drought events are well known in the Iberian Peninsula. We can mention for example the outstanding 2004-2005 drought in the Iberian Peninsula (Garcia-Herrera et al. 2007) or the record Winter drought of 2011-12 in the Iberian Peninsula (Trigo et al. 2013). We can also mention the 2009-2010 extreme winter precipitation in the Iberian Peninsula (Vicente-Serrano et al. 2011). Therefore, severe and long drought events are frequent in the IP and are getting even more severe in the last decades (Trigo et al. 2013). This increasing severity is accompanied by an increased tendency for dryness and decrease of vegetation cover, due to the higher atmospheric evaporative demand (Vicente-Serrano et al., 2012, 2014). This is reflected on the higher trends of SPEI than for SPI in the IP.

There is no doubt that all these extreme events have been previously assessed and many questions arose. Is there a trend? Are these widespread, outstanding, extreme events becoming more intense? More frequent? These are interesting research questions, but we do not intend to reply to these questions in this paper.

However, when studying extreme events another question arises: how can we compare two outstanding events? Which (dry or wet) extreme is the most extreme? Should we consider the most extreme the longest? The largest? How should we compare a smaller, very intense extreme with a larger, less intense extreme? Therefore, this paper intends to discuss only this topic. Future work may eventually use this ranking to identify variability and trends of extremes, but this is not the scope of this paper.

*“It should be stressed that although the high number of events (dry and wet) for the XXI century on the ranking, the present methodology does not allow (neither aims) to point to a trend of extreme events on IP during the last decades.”*

- Barriopedro D., Gouveia C.M., Trigo R.M., Wang L. (2012) The 2009/10 Drought in China: Possible Causes and Impacts on Vegetation. *Journal of Hydrometeorology*, Vol 13. DOI: 10.1175/JHM-D-11-074.1
- Garcia-Herrera R., Paredes D., Trigo R.M., Trigo I.F., Hernández H., Barriopedro D., Mendes M.T. (2007) The outstanding 2004-2005 drought in the Iberian Peninsula: associated atmospheric circulation. *Journal of Hydrometeorology*, 8, 483-498
- Sousa P., Trigo R.M., Aizpurua P., Nieto R., Gimeno L., Garcia-Herrera R. (2011) Trends and extremes of drought indices throughout the 20th century in the Mediterranean. *Natural Hazards and Earth System Sciences*, 11, 33-51, doi:10.5194/nhess-11-33-2011
- Trigo R.M., Añel J., Barriopedro D., García-Herrera R., Gimeno L., Nieto R., Castillo R., Allen M.R., Massey N. (2013) The record Winter drought of 2011-12 in the Iberian Peninsula, in *Explaining Extreme Events of 2012 from a Climate Perspective*. *Bulletin of the American Meteorological Society*, 94 (9), S41-S45
- Trigo R.M., Gouveia C., Barriopedro D. (2010) The intense 2007-2009 drought in the Fertile Crescent: Impacts and associated atmospheric circulation. *Agricultural and Forest Meteorology*, 150, 1245-1257
- Vicente-Serrano S. M., Lopez-Moreno Juan-I., Beguería S., Lorenzo-Lacruz J., Sanchez-Lorenzo A., García-Ruiz J. M., Azorin-Molina C., Morán-Tejeda E., Revuelto J., Trigo R., Coelho F., Espejo F. (2014) Evidence of increasing drought severity caused by temperature rise in southern Europe. *Environmental Research Letters*, doi:10.1088/1748-9326/9/4/044001
- Vicente-Serrano S. M., S. Beguería, J. Lorenzo-Lacruz et al., (2012) "Performance of drought indices for ecological, agricultural, and hydrological applications," *Earth Interactions*, vol. 16, no. 10, pp. 1–27.
- Vicente-Serrano S.M., Trigo, R.M., Liberato M.L.R., López-Moreno J.I., Lorenzo-Lacruz J., Beguería S., Morán-Tejeda H., El Kenawy A. (2011) Extreme winter precipitation in the Iberian Peninsula, 2010: anomalies, driving mechanisms and future projections. *Climate Research*, 46, 51-65, doi: 10.3354/cr00977

221-234. Remove 18 and 24 months. Persistence should be also recorded with 6-and 12-month SPEI and it is not affected by the mentioned autocorrelation problems.

REPLY: Please see previous answer to your comment on line 166.

236-244. I would not use different thresholds. This makes the structure of the article more complex unnecessarily.

REPLY: As we have explained previously, we are hierarchizing extreme events taking into account both the intensity and the affected area. This is the novelty. The methodology aims at assessing how intensity and area contribute to the extreme events. Therefore, a sensitivity analysis on the impact of different thresholds to define dry and wet events is performed. This is fundamental to assess how the ranking depends on the intensity.

Figure 1. Is this needed?

REPLY: We agree that for someone who studies the Iberian Peninsula this figure would not be relevant. However, the scope of this journal is global, and the figure helps someone who is not so familiar with Europe to better identify the study region.

Discussion: There is not a discussion section that discusses in depth the obtained results and some comparison with the scientific literature related to droughts published in the Iberian Peninsula in recent years. I think extremely necessary to write an independent discussion section in which the caveats of the data and methodology are stressed, but also the implications in the current climate change scenario and the possible novelty of the results in relation with the existing literature.

REPLY: We agree with the reviewer that a discussion section may be included to stress some of the identified caveats, advantages and disadvantages of this methodology. Nevertheless, we would like to stress that, to the best of our knowledge, this is the first and only paper to present a methodology to rank extreme (dry and wet) events in the Iberian Peninsula. Moreover, we stress, this paper does not study droughts (or floods). However, recognizing the need for a more proficient discussion, as pointed by the reviewer's comments, we will include in the discussion section some highlights for future research questions which may be addressed after a ranking methodology and dataset is published.

Thank you!