Classifying compound coastal storm and heavy rainfall events in the north-western Spanish Mediterranean" by Marc Sanuy et al.

Anonymous Referee #3

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We thank the reviewer for the detailed review and constructive comments on the manuscript. We have performed a thorough revision to address all the comments, as detailed below.

This manuscript summarized results from a comprehensive analysis of compound coastal storms and heavy rainfall events in parts of Spain. Two types of compound events are assessed, namely multivariate compounding events and spatially compounding events. The analysis uses a mixture of observational data and model hindcasts, as well as atmospheric reanalysis data to assess synoptic weather types associated with certain compound events. The analysis and results are very interesting and worthy of publication with NHESS. A general comment is that the discussion could use more work as much of it reads more like results (this also relates to my comment below on what the impact of concern is when assessing for example spatially compounding events). Other than that I only have a list of mostly minor specific comments listed below that should be taken into account before the paper is ready for publication.

[R3.1] As previously mentioned, the Discussion section will undergo a thorough review (see answers to R1.1 and R2.1).

37 Berghuijs et al.

[R3.2] This will be addressed in the revised version of the manuscript.

40 The way it's worded indicates that Ward et al. considered storm surge and waves which is not true. Marcos et al. is a good reference for that and should be added: https://doi.org/10.1029/2019GL082599

[R3.3] The sentence will be rephrased to "… by marine drives, such as waves and/or surge". The reference will be added to the reference list.

56 I would refer to those as "regional" instead of local

[R3.4] We will refer to them as "smaller regional scales".

75-82 What about spatially compounding with the same driver, i.e. spatial footprints (as analyzed here for example: https://doi.org/10.1029/2020JC016367), in my opinion that also falls into that category.

[R3.5] This aspect regards with the definition of compound event itself, and in spite that this situation could be relevant from the risk-management standpoint, here we consider this as a single coastal storm event (wave or surge) affecting a large part of the territory. In this study, we just consider compound events as those involving the co-occurrence of the two analysed components (rain and coastal -wave- storms) at the regional scale. (see answer to R2.14).

99 a bit more discussion about why events like that are of particular interest would be useful, what is the particular impact of concern for both types of events, multivariate or spatially compounding, in the context of this analysis?

[R3.6] The Discussion section will undergo a thorough review. All text related to the description of specific episodes will be moved to a new subsection under Results. Additionally, the Discussion section will also address reviewers' comments and suggestions. With regards to the reviewer's specific comment, the two types of analysed compound events are compared in terms of their induced damages across the territory and how they can condition risk management operations. (see answer to comment R1.3)

165 Was there a particular reason to choose that reanalysis instead of a higher resolution one like ERA5? Do the authors expect all relevant features to be captured at this resolution?

[3.7] NCEP has been used as has been done in other articles (Wu et al., 2018). Since the main objective was to characterize synoptic weather conditions responsible for observed compound events, it is considered valid enough to represent the synoptic conditions that characterize them. It would not be the case, for instance, if you wanted to characterize mesoscale conditions. Examples of its application to characterize the types of circulation are in the special issue on circulation-type classifications (Einar and Huth, 2016), applications at the Mediterranean region by El Kenawy et al., (2014), Duane and Brotons (2019), Peña-Angulo et al., (2020) or Hochman ey al., (2020), and its application to the study area by Gilabert and Llasat (2017) or Lemus-Canovas et al (2019).

Additionally, it's easy to access, manage and download using programs in R.

El Kenawy, A. M., McCabe, M. F., Stenchikov, G. L., & Raj, J. (2014). Multi-decadal classification of synoptic weather types, observed trends and links to rainfall characteristics over Saudi Arabia. *Frontiers in Environmental Science*, *2*, 37. Doi: 10.3389/fenvs.2014.00037

Duane, A., & Brotons, L. (2018). Synoptic weather conditions and changing fire regimes in a Mediterranean environment. *Agricultural and Forest Meteorology*, *253*, 190-202.

Peña-Angulo, D., Nadal-Romero, E., González-Hidalgo, J. C., Albaladejo, J., Andreu, V., Bagarello, V., ... & Zorn, M. (2019). Spatial variability of the relationships of runoff and sediment yield with weather types throughout the Mediterranean basin. *Journal of Hydrology*, *571*, 390-405.

Hochman, A., Alpert, P., Kunin, P., Rostkier-Edelstein, D., Harpaz, T., Saaroni, H., & Messori, G. (2020). The dynamics of cyclones in the twentyfirst century: the Eastern Mediterranean as an example. *Climate Dynamics*, *54*(1), 561-574.

Lemus-Canovas, M., J.A. Lopez-Bustins, L. Trapero, J. Martin-Vide, 2019. Combining circulation weather types and daily precipitation modelling to derive climatic precipitation regions in the Pyrenees. Atmospheric Research 220 (2019) 181–193.

Einar, O., and R. Huth, 2016. Circulation-type classifications in Europe: results of the COST 733 Action. Int. J. Climatol. 36: 2671–2672 (2016). DOI: 10.1002/joc.4768 8 pp.

Gilabert, J. and M.C. Llasat, 2017. Circulation weather types associated with extreme flood events in Northwestern Mediterranean. Int. J. Climatol. (2017) Published online in Wiley Online Library (wileyonlinelibrary.com) DOI: 10.1002/joc.5301 Q1.

184 “verify” is used several times in the wrong context

[R3.8] This will be addressed in the revised version of the manuscript

219-231 I understand that this would not include events where one variable is extreme and the other one is not (but might still be elevated, though not enough to cross the “extremes” threshold), is that correct? How does that relate to other approaches that are often used, such as two-sided sampling, where each extreme event of either variable is paired with the simultaneous value of the other variable (regardless whether the latter is extreme or not)

[R3.9] That’s correct. Events where only one variable is extreme (It exceeds the threshold to be classified as extreme) are not included in the assessment. This approach has been adopted because this is mainly a risk-management oriented study. It is assumed that a given climatic variable (waves or rainfall) below the considered threshold is not producing a significant impact on the system by itself, neither its combination with an extreme one will substantially increase its associated risk. These events are considered as a single (univariate) extreme event. Their inclusion in the analysis would imply (in practice) to analyse all recorded univariate events and, thus, to substantially introduce noise in the analysis without providing significant information on compounding effects (which are the main target).

252 “correlation-based, gridded map-typing technique” is a mouthful and could use some further explanation.

[R3.10] This will be rephrased to: “… a correlation-based method” and later in L254: “… the method consists on obtaining map patterns using the Pearson product-momentum correlation (rxy, eq.2) to depict the degree of similarity of spatial structures between pairs of gridded data (i.e. the map typing focuses on the positions of high- and low-pressure centres, rather than their magnitudes)”.

265 More out of curiosity, do the authors have an idea how this compares to K-Means clustering?

[R3.11] The popularity of correlation-based map-pattern classification springs from its intuitive and simple basis of automating the same task performed manually by an analyst (Yarnal, 1993 Yarnal et al., 2001). Its product is easily read and understood by the user. It also produces a good separation between weather types, i.e., a good degree of similarity among the cases within the same cluster and dissimilarity between the clusters (Huth et al., 2008). One of its main limitations is that is not as consistent as other approaches such as K-mean clustering or PCA, as it is in general sensitive to the choice of parameters that must be set a priory (such as the cutting threshold). This is also related to the fact the method tends to produce one big class followed by minor ones (snowballing effect). However, these limitations where minimized by performing a two-step comparison between classes, i.e. a first classification with low thresholds (rt=0.2) and a second classification using the preliminary classes obtained in the first and maximizing the correlation coefficient (rt), which lead to the final classes with two big groups (~40% of cases) and a follow-up one (~20% of cases). On the contrary, one of the main limitations of a clustering-based method is its tendency to produce homogeneous (equally populated) groups.

The discussion section will be completed with a paragraph describing the advantages and limitations of the chosen method and how it compares with manual, cluster-based and PCA techniques.

References:

Yarnal, B. Synoptic climatology in environmental analysis. London, UK: Belhaven Press. 1993.

Yarnal, Brent, et al. "Developments and prospects in synoptic climatology." International Journal of Climatology: A Journal of the Royal Meteorological Society 21.15 (2001): 1923-1950.

Huth, Radan, et al. "Classifications of atmospheric circulation patterns: recent advances and applications." Annals of the New York Academy of Sciences 1146.1 (2008): 105-152.

373 consider changing “generating floods” to “generating rainfall”, as sea storms can also lead to floods.

[R3.12] This will be addressed following reviewer’s suggestion.

Caption of Table 3: should it be Figures 11 and 12?

[R3.13] Yes, it should. This will be addressed in the revised version of the manuscript.