

## ***Interactive comment on “Extreme wet seasons – their definition and relationship with synoptic scale weather systems” by Emmanouil Flaounas et al.***

### **Anonymous Referee #2**

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### **GENERAL COMMENTS**

This study provides a novel analysis of what the authors refer to as extreme precipitation seasons, defined as 90-day periods during 1979–2018 exhibiting especially large precipitation accumulations. A global climatology of these seasons is constructed and their characteristics are examined through statistical analysis. Contemporaneous global climatologies of warm conveyor belts, tropical moisture exports, breaking Rossby waves, and cyclones are employed to examine dynamical processes that contribute to the extreme seasons.

Overall, I found this study to be interesting and novel, and I believe that the topic fits

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within the scope of Weather and Climate Dynamics. The methods developed to identify extreme precipitation seasons and extreme season patches are innovative and novel, though, in my opinion, somewhat complicated. This is the first study to construct a global climatology of extreme precipitation seasons and to attempt to relate them to different types of weather systems. I believe that the study addresses important gaps in scientific understanding regarding the occurrence of extreme precipitation seasons. Despite the strengths of this study, there are a number of issues that need to be addressed with regard to the clarity of the writing, interpretation of the results, the methodology, and the background discussion.

### SPECIFIC COMMENTS

Abstract: The abstract is quite lengthy and complicated. I recommend simplifying and shortening it.

line 43: I recommend being more specific regarding the socioeconomic impacts of these events.

line 47: I suggest also mentioning climatological studies of relationships between PV streamers/breaking waves and precipitation extremes (e.g., Martius et al. 2006; de Vries et al. 2018; Moore et al. 2019).

line 51: It is unclear what exactly you mean by 'environmental risks' in this context. Please clarify.

line 53: Specify what impacts the hurricanes caused and the coastal regions of the United States that they affected.

line 53–54: Note, however, that the season did include several extreme-rain-producing hurricanes.

line 54: Specify what the 'main impact' was? Was it prolonged regional flooding?

line 56: Please provide a reference for this statement.

line 111: Please explain why this model-based dataset was used. Also, please state any caveats that must be considered when using coarse-resolution model-based precipitation data.

line 155–158: In my view, the authors have not provided sufficient context and background information to motivate examination of relationships to these different weather systems. This sentence is inadequate in this regard and does not fully and accurately describe the influence that these systems can have on precipitation. For instance, the authors fail to mention that PV streamers and cut-offs have also been found to be linked to strong water vapor transports and dynamical lifting. The four weather system types and their dynamical relationships to precipitation extremes should be described in more detail in the introduction section. Also, it could be worthwhile to describe inter-relationships between the four types of systems.

line 168: I suggest using a consistent term for the extreme seasons throughout the paper. Use either "extreme wet season" or "extreme precipitation season" but not both.

169–171: While I understand your justification for classifying these seasons as extreme, I am still unsure whether I agree with it. If the seasonal precipitation does not deviate much from climatology, then it really is indicative of an ordinary precipitation season. Are there ways to avoid inclusion of so many secondary seasons in the dataset? Could you use more restrictive criteria to identify secondary extreme seasons? Could you just consider the primary extreme seasons and not the secondary seasons?

line 178: Perhaps insert "and occur most frequently" after "most intense"?

line 184: "This suggests..." I do not see how a lack of a sharp land–sea distinction itself suggests that a given region is influenced by atmospheric rivers and cyclones. It would be more precise to say that the lack of a distinction suggests that a region is influenced by landfalling systems originating over the ocean, such as extratropical cyclones and atmospheric rivers.

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line 194–197: Apologies for my confusion, but I am having trouble reconciling this sentence with the previous sentence. If only results for primary seasons are presented, then how can there be multiple extreme seasons at a given grid point.

line 222: “arid areas”: I suggest providing specific examples of these areas to aid the reader.

line 225: “climatologically wet regions”: I suggest providing specific examples of these regions to aid the reader.

line 273: Please provide references for the 2010 and 2017 hurricane seasons.

line 351: It is not clear to me how unusual the frequencies of cyclones, streamers, and TMEs depicted in Figs. 8 and 9 are for those regions and seasons. It would be helpful to compare the feature frequencies to the climatological frequencies for the time periods, as was done in Fig. 10.

line 363–364: “However, the two...” It is unclear to me what the purpose of this sentence is.

line 364–365: “The synergy...” The meaning of this statement is ambiguous to me. Which processes are you referring to?

line 365: “Finally, most...” Mention that this statement applies specifically to the 1992–1993 event.

line 365–367: “However, this comes...” What is the basis for this statement? Please provide a supporting reference.

line 373: “In this region...” This is not true. Cyclones can and do occur at these latitudes, as clearly depicted in Fig. 9.

line 373–374: “However, RWB...” A figure reference is needed in this sentence.

line 374: By “upper-tropospheric systems” do you mean elongated PV streamers as-

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sociated with RWB? If so, consider saying "The upper-level PV streamers resulting from the events". Upper-level is more accurate than upper-tropospheric here given that these systems are defined as narrow filaments of stratospheric high-PV air.

line 389: The anomalous warmth could also reflect frequent poleward excursions of warm, moist air into the Arctic that supported the precipitation within the patch.

line 392: "probably reflect. . ." this assertion does not appear to be supported by any evidence.

line 416: What do you mean by "the largest part of the world"?

line 417: Does this imply that the cyclone climatology used in this study also includes tropical cyclones and other tropical low pressure systems in addition to extratropical cyclones? Is there any distinction made in the climatology between extratropical and tropical systems?

line 422–423: I find this sentence confusing. Which result is in accordance with Pfahl and Wernli (2012)? Also, it is a sentence fragment.

line 430: it would be more dynamically accurate to say "baroclinic zones associated with cyclones" instead of "cyclones' frontal surfaces"

line 437: "physical characteristics" is vague. Please specify the physical characteristics that are relevant in this context.

line 443–444: "Therefore, TMEs. . ." This statement strikes me as erroneous. Can you cite a study that supports this claim? My understanding is that a TME will only support heavy precipitation where it encounters a region of strong ascending motion; thus, TMEs should not be expected to produce high amounts of precipitation whenever they reach higher latitudes but rather only under certain circumstances.

line 448–449: "Occasionally, TMEs. . ." I find this sentence somewhat confusing. Please rephrase more clearly.

line 454–455: I do not entirely follow this reasoning. The ratios shown in Fig. 12 do not necessarily indicate the strength of the contribution of a given type of weather system. They only indicate the degree to which weather system frequencies deviate from climatology during extreme precipitation seasons. It seems to me that it is still possible for systems to produce large portions of the precipitation during extreme seasons even if their frequencies do not deviate substantially from climatology.

line 457: It would be more precise to say “PV streamers” rather than “filaments”

line 459: What do you mean by “RWB into the tropics”? Perhaps it would be more accurate to say “extension of PV streamers into the tropics”.

line 461–463: “It is noteworthy that. . .” I really do not understand this sentence. Please clarify.

line 463–464: “Finally, the. . .” This sentence does not make sense to me.

line 464–466: “Indeed, WCBs. . .” I do not understand how this sentence connects with the preceding discussion in this paragraph.

line 488: It seems to me, based on the results in Figs. 8–11, that large patches can also result from synoptic-scale weather systems, such as extratropical cyclones and RWB. This should also be mentioned here.

line 499–500: The streamers that form in connection with wave breaking tend to be part of baroclinic waves that are tilted with height. Thus, widespread heavy precipitation produced in association with wave breaking is often displaced downstream and spatially separated from the upper-level streamer. The approach for linking RWB to the extreme precipitation seasons in this study does not appear to directly account for this fact.

## TECHNICAL CORRECTIONS

line 43: “always” -> “long”

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line 46: remove “a high number of”

line 57: “The factors. . .” Perhaps start a new paragraph here?

line 72: “aggregation” -> “accumulation”

line 81: “The grand” -> “A large”

line 84: “state of the art” -> “scientific understanding of this topic”

line 90: “this chain of events” -> “the chain of events governing precipitation”

line 93–94: I suggest inserting citations immediately after the corresponding phenomenon in the list. For instance, “cyclones (Pfahl and Wernli 2012), fronts (Catto et al. 2012), warm conveyor belts (Pfahl et al. 2014)...”

line 98: would “the frequency and intensity of the precipitation it produces” be more precise than “its frequency and its intensity”?

line 175: “mainly” -> “predominantly”

line 178: “me” -> “be”

line 179: “Indian Ocean)”

line 186: insert “evident in” after “are”

line 193: insert “results for” after “Only”

line 213: Insert “the number of” before “ratio of”

line 222: “few more” -> “a small increase in the number of”

line 232: “the grand” -> “a large”

line 272: “depict” -> “correspond to”

line 273: “includes the track of” -> “corresponds to”

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line 352: remove “is” after “It”

line 360: “highlight the important link” -> “suggest links”

line 361–363: delete “Pfahl et al. (2014) showed that” and insert the (Pfahl et al. 2014) at the end of the sentence.

line 377: “make” -> “made”

line 381: insert “necessarily” after “should not”; replace “in the sense that” with “because”; replace “is due” with “can be due”

line 416: “formation” -> “occurrence”

line 439: “the scarcity” -> “climatological infrequency”

line 440: “contributes to” -> “can result in”

line 443: “to moist plumes that originate” -> “transports of moist air”

line 487: “methodology” -> “method”

line 492–493: “considering their...” This is awkwardly worded. Please rewrite.

line 495: insert “, respectively” after “tropics”

line 512: “strongly” -> “highly”

Figure 2: “rainfall” should be changed to “precipitation”

Figure 4: Recommended edit to the caption: “and (b) the ratio of the number”

Figure 5: What is a precipitable day?

Figure 11: The panels should be labeled (a) and (b).

Figure 12: It is unclear to me what you mean by “illustration started from the patch presenting the lowest ratio”

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## REFERENCES

de Vries, A. J., H. G. Ouwersloot, S. B. Feldstein, M. Riemer, A. M. El Kenawy, M. F. McCabe, and J. Lelieveld, 2018: Identification of tropical-extratropical interactions and extreme precipitation events in the Middle East based on potential vorticity and moisture transport. *J. Geophys. Res.: Atmos.*, 123, 861–881, doi:10.1002/2017jd027587.

Martius, O., E. Zenklusen, C. Schwierz, and H. C. Davies, 2006: Episodes of Alpine heavy precipitation with an overlying elongated stratospheric intrusion: A climatology. *Int. J. Clim.*, 26, 1149–1164, doi:10.1002/joc.1295.

Moore, B. J., D. Keyser, and L. F. Bosart, 2019: Linkages between extreme precipitation events in the central and eastern U.S. and Rossby wave breaking. *Mon. Wea. Rev.* (in press), doi:10.1175/MWR-D-19-0047.1

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Interactive comment on *Weather Clim. Dynam. Discuss.*, <https://doi.org/10.5194/wcd-2020-28>, 2020.

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