Review for “Classification of Large-Scale Environments that drive the formation of Mesoscale Convective Systems over Southern West Africa” by Nkrumah et al.

Overview

The present manuscript links large-scale atmospheric patterns over West Africa with the occurrence of mesoscale convective systems (MCSs) over the largely understudied southern West African (SWA) region. By applying the self-organizing maps (SOM) technique on a long-term (40-year) ERA5 reanalysis dataset, the authors identified six major atmospheric patterns (“nodes”) which broadly represent the rainy and dry seasons of SWA (pre-, peak, post-monsoon). Making use of satellite-based METEOSAT infrared images over 12 years, anomaly patterns from the mean state of the nodes are evaluated to infer typical environmental conditions for the development of MCSs. Here, the authors identified a high-moisture/high-shear environment to be favourable for MCS development under all node situations. While high moisture load is driven by enhanced low-level south-westerlies, stronger shear can be attributed to a warmer Sahel and thus enhanced mid-level easterlies as a consequence of a stronger temperature gradient over West Africa.

As the authors pointed out, drivers of rainfall over the densely populated SWA are still understudied, largely due to the complex and variable interplay between the West African monsoon circulation and local to regional characteristics such as topography or coastal effects. Thus, studies dedicated to SWA like the present manuscript can be a welcome addition and of certain relevance for the scientific community. Overall, I like the paper for its comprehensible presentation and conciseness, however, the latter of which I also see as a shortcoming at places. More details are given in the comments below. Although I do think that, on their own, the comments are largely minor, it can be major if accumulated. Otherwise, I believe the methods used in this study are generally sound. The topic of the manuscript fits within the scope of the journal.

General comments/questions

- The authors used 1200 UTC and 1800 UTC, respectively, as the reference times for pre-MCS conditions and the identification of an “MCS day”. While this is intuitive in many ways (e.g. highest occurrence frequency of convection in the afternoon/early evening), an entity that is excluded with this definition are nighttime, potentially fast-moving convective systems (e.g. squall lines), which also occur over SWA (Fink and Reiner (2003)) and which can also be important rain contributors in the region (Maranan et al. (2019)). Although I acknowledge that a full analysis exceeds the scope of this study, I believe it is worth including and discussing them (e.g. at 2100 UTC vs 0300 UTC, provided the sample size is high enough), for instance, by extending Fig. 10 by this subset of nighttime convection. I can imagine that, lacking CAPE during the night, these convective systems are increasingly shear-driven.

- Likewise, I do think it is worthwhile to investigate the environmental conditions of “no-MCS” cases. As far as I’ve understood, the mean-state composites contain all daily timesteps in the 1980-2020 period. Therefore, the anomalies for this case can be integrated in Fig. 10 as well.

- When CAPE is discussed, CIN should be evaluated alongside. This might even be of some relevance for the “no-MCS” cases in the previous bullet point.

- Can the authors explain why they changed from 925 hPa specific humidity in Fig. 3 to TCWV in Fig. 10? Although TCWV is primarily influenced by the evolution of the humidity field in the lower troposphere, I would stay consistent here by choosing one.

- A couple of question regarding MCS data and definitions which may be clarified in the manuscript as well:
    1. Can the authors elaborate why METEOSAT data is limited to 2015?
    2. Have the authors used 15-minute METEOSAT data?
    3. What do the authors mean by “5 MCS snapshots”? The detection of at least 5 MCSs or the detection of MCSs at five timesteps between 1600 and 1900 UTC? If the latter, is an MCS day identified irrespective of the overall number of MCSs at 1800 UTC? So the detection of a single MCS is sufficient?

4. Are only land-based MCSs accepted? What would be the criterion for the position? Center of mass?
5. How did the authors determine the rainfall amount? What dataset is used for this?

- Up until Fig. 6, the extent of the "SWA region" never became clear. The authors may consider including an introductory map of West Africa (e.g. orography) with the SWA region outlined.

- Can the authors clarify in more detail how node 4 and 5 have to be distinguished in the context of the evolution of the WAM? From Fig. 2, the only major difference I can spot is that the background geopotential in node 5 is higher than in node 4. Is that also what the SOM technique identified as the decisive difference to define a dedicated node?

- What atmospheric patterns are shown in the remaining three nodes which were dismissed for this study? How many days were then excluded from the overall sample?

Specific comments/questions

L42: What reference is "Change 2014"?

L76: "In previous studies that evaluated MCS-favouring atmospheric environments, less attention was given to the importance of large-scale WAM modes and their effect on regional MCS frequencies in SWA". Nonetheless, there are studies that address the large-scale settings for WAM-related rainfall throughout the seasons, e.g. the studies by Sultan and Janicot (see reference). Although they do not refer specifically to MCSs, MCSs are part of the WAM rainfall patterns.

L95: "For this purpose, a classification using a self organizing map (SOM; Kohonen 2001) analysis was carried out to characterize large-scale WAM patterns during the 1981-2019 period". Any reason why the mapping was performed until 2019, but the analysis of atmospheric fields until 2020?

L109: Better "137 vertical <u>model</u> levels".

L111: Can the authors explain what they used the 250 hPa horizontal wind for? Have the authors also investigated the Tropical Easterly Jet? In any case, the 250 hPa wind was never addressed anymore.

L129-133: Might be better to shift this to the introduction.

L168: Seasonal cycle of what? Monthly rainfall amount?

L185: Do you mean "low pressure"?

L214: "…show significant changes over the last 4 decades". In what way exactly?

Sec. 4.2: Have the anomalies been calculated from the mean state in Fig. 2, i.e. based on 1981-2020? Since the MCS days run from 2004-2015, have the authors account for potential trends between the periods 1981-2003 and 2004-2015?

Figure 5: A bit surprising to find zero MCSs in February, but probably a consequence of the high areal MCS criterion chosen in this study.

L227: Again, the definition of the SWA domain needs to be outlined earlier.

Figure 6: Again, does "location of the MCS" refer to the center of mass of the cloud area? Does the MCS frequency refer to the amount of MCS days compared to the total number of node days? Does that explain why there are much more MCS dots for node 6 than node 5, the latter of which has a higher frequency?

L248: What do the authors mean by "insignificant behaviour"?

L250: Also seemingly partly northerlies from the Mediterranean region.

Figure 8: Can the authors add the maps for the mean-state of vertical wind shear in section 4.1 and discuss them for more clarity?

Figure 9: As mentioned, CIN should be shown and discussed as well.

L309: "…illustrating the relatively storm-hostile mean conditions…". But doesn't the mean state include all time steps, including MCS days? As outlined in the general comments, the authors may add the specific non-MCS state in Fig. 10 for clarity.

Figure 10: The reddish colours are hard to distinguish.

References

Fink, A. H., & Reiner, A. (2003). Spatiotemporal variability of the relation between African easterly waves and West African squall lines in 1998 and 1999. Journal of Geophysical Research: Atmospheres, 108(D11).

Maranan, M., Fink, A. H., Knippertz, P., Francis, S. D., Akpo, A. B., Jegede, G., & Yorke, C. (2019). Interactions between convection and a moist vortex associated with an extreme rainfall event over southern West Africa. Monthly Weather Review, 147(7), 2309-2328.

Sultan, B., Janicot, S., & Diedhiou, A. (2003). The West African monsoon dynamics. Part I: Documentation of intraseasonal variability. Journal of Climate, 16(21), 3389-3406.

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