RESPONSE TO RC2

Referee #2: We thank the referee for their valuable input, which helped to improve the clarity of our manuscript and figures. The line references below refer to the newly changed manuscript. Additionally, we provide a document with tracked changes.

General comments:

1) The SOM analysis should be presented as a whole, and the reason for rejecting certain nodes from the analysis should be better explained. No discussion is dedicated to the SOM configuration, primarily the choice of the number of nodes, but also other SOM parameters (neighborhood size, topology, initial coverage space, etc.). The robustness of the SOM clustering is not evaluated. A significance test should be added for the detected geopotential patterns, and the SOM errors (quantification and topological) should be discussed. Furthermore, the low number of nodes under consideration for this study appears to not fully justify a SOM analysis in the first place. Seeing as each node roughly corresponds to a certain season and is treated as a seasonal mean, it appears that the information presented here can be yielded by a simple seasonal decomposition. Ideas to enrich the SOM analysis and the gain from it can be found in the literature quoted by the authors. Otherwise, the authors may consider replacing the SOM analysis with a simple seasonal decomposition. Please also refer to more specific comments in this regard, below, and the following highly relevant references with very similar motivations and methodologies:

- Liu, Y., Weisberg, R. H., and J. I. Mwasiagi (Eds.): A review of self-organizing map applications in meteorology and oceanography, Self-Organizing Maps: Applications and Novel Algorithm Design, InTech publications, Rijeka, Croatia, 2011.
- Gueye AK, Janicot S, Niang A, Sawadogo S, Sultan B, Diongue-Niang A, Thiria S 2010 Weather regimes over Senegal during the summer monsoon season using self-organizing maps and hierarchical ascendant classification. Part I: synoptic time scale. Climate dynamics. doi:10.1007/s00382-010-0782-6
- Espinoza, J. C., Lengaigne, M., Ronchail, J., and Janicot, S.: Largescale circulation patterns and related rainfall in the Amazon Basin: a neuronal networks approach, Clim. Dynam., 38, 121–140, https://doi.org/10.1007/s00382-011-1010-8, 2012
- Givon, Y., Keller Jr, D., Silverman, V., Pennel, R., Drobinski, P., & Raveh-Rubin, S. (2021). Large-scale drivers of the mistral wind: link to Rossby wave life cycles and seasonal variability. Weather and Climate Dynamics, 2(3), 609-630.

The comments and suggested references are well received. However, we will like to address these comments as follows:

First, we do state that we use a 9-node SOM however, 6-nodes are representative of the West African monsoon pattern and that is why we present the 6-node states. We should mention that to obtain the best SOM, the third stage of the SOM process evaluates the quantization and topological error. An optimal SOM is obtained when the average Euclidean distance is the minimum (the quantization error is the smallest) and when the proportion of all data vectors for which the first and second best matching units are not adjacent is also minimum (the topological error is the lowest). Once the average quantization error has been minimized, the relationships between the predictor and node data are investigated.

Third, we do not agree with using a simple seasonal decomposition method for this analysis as the SOM has clear strengths when compared with a simple seasonal decomposition. For instance, a simple seasonal

decomposition may not identify the combined or mixed pre/post-monsoon states (secondary states) and is likely to identify states as either pre or post-monsoon (primary states), and we will be clearly losing vital information (e.g., Rousi et al. 2015).

In testing for the significance of the identified SOM states, there are several studies (e.g., Hewitson and Crane, 2002; Rousi et al. 2015; Espinoza et al 2012) that support our methodology on the fact that the SOM methodology is data-dependent and such the dominant patterns are representative of the data, thus in the current study a significance test is not necessarily needed. Also, the initial coverage space is mentioned in the data section (domain). We must also highlight here that the SOM is a neural network algorithm as clearly shown in the reviewer's suggested literature (Espinoza et al. 2012).

Nonetheless, we have made additions to the methodology section to provide further clarity and to reflect the reviewer's suggestions.

In this study, the SOM is randomly initialized allowing for hidden patterns and structure in the geopotential height at 925 hPa to be discovered while the algorithm iteratively updates the weights of the nodes to better represent the data. The strength of initializing the SOM this way lies also on its robustness to noise and outliers as a result of the algorithm applying a competitive learning structure to the data which then allows for the formation of distinct clusters. The SOM_PAK algorithm allows the SOM process to minimize quantization and topological errors at the mapping stage when choosing the best SOM as outlined in Lennard and Hegerl (2014). However, there is a trade-off when choosing the size of the SOM, as this is dependent on the need to generalize circulation states for analyses or the need to capture predominant spatial characteristics that affect the local climate. Thus, in this study, we have tested several sizes of the SOM and have arrived at using a 9-node SOM. As depicted in Fig. S1 for a 9-node SOM, it is evident that some nodes are still redundant, and this is a compromise on states not being overly generalized while capturing the dominant spatial characteristics over the region. Here, we agree on six nodes, which allow distinct synoptic states to be reproduced while grouping nodes that are similar. This grouping was done based on similarities in atmospheric patterns and seasonal frequency from the 9-node case.

2) The choice of low-level geopotential heights as a clustering agent should be better motivated, given the relatively low correspondence between it and the low-level winds in the domain, which are described as the main process driver throughout the manuscript. Have the authors considered directly classifying the wind field?

The choice of low-level geopotential height was made in this manuscript because we wanted to consider somehow the influence of the West African Heat Low (WAHL) in influencing instability. At low levels, the geopotential height well describes the strength of the WAHL (Lavaysse et al. 2009; Biasutti et al. 2009).

3) Nodal trends – this section appears unrelated to the motivations of the paper and is very slim. I suggest a deeper analysis to explore, for instance, corresponding trends in MCS events. Otherwise, consider removing this section.

Thank you. This section has been removed.

4) MCS data – I think this data should be further explored. For one, it can be better presented using a density plot. Secondly, spatial variability should be discussed and possibly explained, with an emphasis on variations between nodes and seasons within the nodes. Finally, it's worth checking for MCS behavior on off-season node days.
Thank you for this great suggestion. We consider this suggestion to be an added value to this idea of MCS's impact on the climate of SWA. However, this manuscript tries to understand the conditions surrounding/ favorable to the formation of MCSs. Therefore, we concentrated on the mean position of MCS. Further research work we will consider in the future will pay more attention to the spatial variability of MCSs.

5) The link to predictability can be improved. For instance, can we learn anything from a lagged correlation between nodal transitions and MCS density?
Thank you for the suggestion. We have considered the suggestion and we will be interested to work on that in our future research which will improve the link to predictability.

Specific comments:

- L24: Too vague. What is the input used for classification? i.e., how do you define a "synoptic circulation-type"?

The 925hPa geopotential height is used as input to train the SOM. The archetypal modes of the geopotential height obtained are used to describe the characteristic circulations over the region.

- L32: Unclear. Do you mean vertical/ horizontal wind shear? what is the field under discussion here?

Here we talk about the zonal wind shear. We have made changes to the manuscript to reflect the exact field under discussion

- L35: The use of the term "shear" or "wind shear" when alternatively referring to vertical and zonal shear is confusing. You should specify which shear is under consideration throughout the paper.

Throughout the manuscript, wind shear or shear is used to represent zonal wind shear. We have therefore replaced "wind shear and shear" with "zonal wind shear" throughout the manuscript.

- L49: Missing a link to WAM. The change of subject is too sudden and does not flow from the previous paragraph. Consider opening the section with lines 53-54

We have taken note of this missing link. We have replaced that statement with "One major atmospheric disturbance that contributes to the WAM is the presence of Mesoscale Convective Systems (MCSs) which supply around 30-80 % of the total rainfall during the WAM (Klein et al. 2018)".

- L94: "large-scale patterns" - Too vague. You should name the parameter used for the classification here.

Parameters used to represent large-scale patterns have been stated to clarify the statement on L94.

- L121: "SWA domain" - This domain should either be specified in latitude and longitude boundaries or displayed in a figure earlier on. Possibly both.

The domain of SWA has been shown earlier in Figure 2 with the latitude and longitude boundaries clearly specified in the figure caption.

- L124: This section requires more detail. For instance, what is the SOM topology? It would be useful to add a neighbor distances map and to evaluate SOM errors. The number of members in each cluster should also be given, preferably in Fig 1.

This has been taken into consideration and changes have been made to the section to capture the above suggestion. Based on generated Sammon maps, we were able to detect any error in the SOM easily. These Sammon maps use a non-linear mapping technique to create a two-dimensional image of the reference vectors where the distance between node vectors approximates the Euclidean distances in data space. We obtain a very ordered Sammon map in the training of the SOM, which made for a robust interpretation of nodal relationships. Similar types of circulation are close to each other in the SOM space and dissimilar circulations are furthest from each other, which is a characteristic of self-organizing maps.

- L128-129: This statement is true for many optional classification inputs. In the present study, the focus is on the tropics where geostrophic balance is not obvious, as seen by your results. Therefore, the choice to classify patterns using geopotential heights should be justified.

Different training variables were used to capture the regional atmospheric circulation. Our choice of the geopotential height at the low level was based on its ability to represent the impact of the West African Heat Low on the WAM cycle and also to identify the seasonal monsoon synoptic states over West Africa.

- L131: Each method has its advantages and disadvantages, and each can be more suited for a different study. Refrain from making conclusive statements.

We agree with the reviewer's view on refraining from making conclusive statements. In this line, we were merely reiterating what the literature says, however, we have modified this in the manuscript.

- L132: "data is not discretized and orthogonality is not forced" – Again, these are not clear advantages. The SOM's strengths and weaknesses should be discussed in the context of the present study.

The SOM strengths and weaknesses are discussed briefly in our study and the references given are for further reading. Indeed these strengths are well documented and are clear advantages to methods such as PCA and K-means clustering.

- L142: More information is required on what led to the choice of 9 clusters. Have you evaluated the network errors under the different configurations (SOM size and other parameters) to show that 9 is the most compatible?

The network errors are under different configurations for different sizes (4x4, 3x4, 3x3, and 2x3). On testing various sizes, a 9-node SOM was selected that adequately picks out the seasonal variation of rainfall over the region of study. The 2x3 resulted in a more generalized circulation archetype whiles the 3x3 represented a wider range of circulations with fewer redundancies.

- L153: Why not compare to non-MCS days within the node? This may highlight the signal you are after.

Thank you for the suggestion. This is well agreed but the main focus of the manuscript was to understand the synoptic state of the environment on MCS days. A look at non-MCS days can be done as future work to elaborate on signals.

- L154: regarding the T-test – on Which confidence level was it conducted? have you used any method to detect false positives in the multi-gridded test? See Wilks 2016 for example. Wilks, D.: "The stippling shows statistically significant grid points": How research results are routinely overstated and over-interpreted, and what to do about it, B. Am. Meteorol. Soc., 97, 2263–2273, https://doi.org/10.1175/BAMS-D-15-00267.1, 2016.

The T-test conducted was on a 95% confidence level. Anomaly plots highlight only regions at this confidence level (0.05 significance level) as well as wind vectors.

- L165: Why is the complete SOM not shown? This is not clear. If you choose to discard nodes altogether, you should show the full SOM map (9 nodes) first, then explain why not all nodes are relevant, and which ones were removed. The resulting 6-node SOM map should be shown in the context of the full SOM map, as the node locations on the SOM map are crucial for the SOM interpretation. This also raises the question: are the panels in Figures 2-9 arranged correctly? i.e., are neighboring nodes in these Figures also neighbors in the full SOM map? I suggest repeating the analysis for 6 nodes if that's what you end up analyzing, while completely removing irrelevant dates from the SOM input.

The complete SOM has been shown in an attached supplementary material (Figure S1) with the monthly distribution of node cases. Similar nodes from the 9-node case were combined in attaining the 2 x 3 nodes. We grouped nodes (1, 4, 7), and (6, 9) and kept 2, 3, 5, and 8 separate. That would also give 6 groupings seemingly representative of pre- and post-monsoon (1, 4, 7), peak-monsoon (6, 9), pre-monsoon only but different patterns (2 and 3), and post-monsoon only but different patterns (5 and 8). Nodes 1, 4, and 7 were considered as having out-of-monsoon conditions, with MCSs more likely far south. Nodes 6 and 9 show somewhat more Sahelian conditions while the tendency for monsoon retreat conditions was evident in nodes 5 and 8. We also observed pre-onset conditions in node 2 and in weaker terms in node 3. We have added some additional text to provide clarity for readers in Section 3.1.

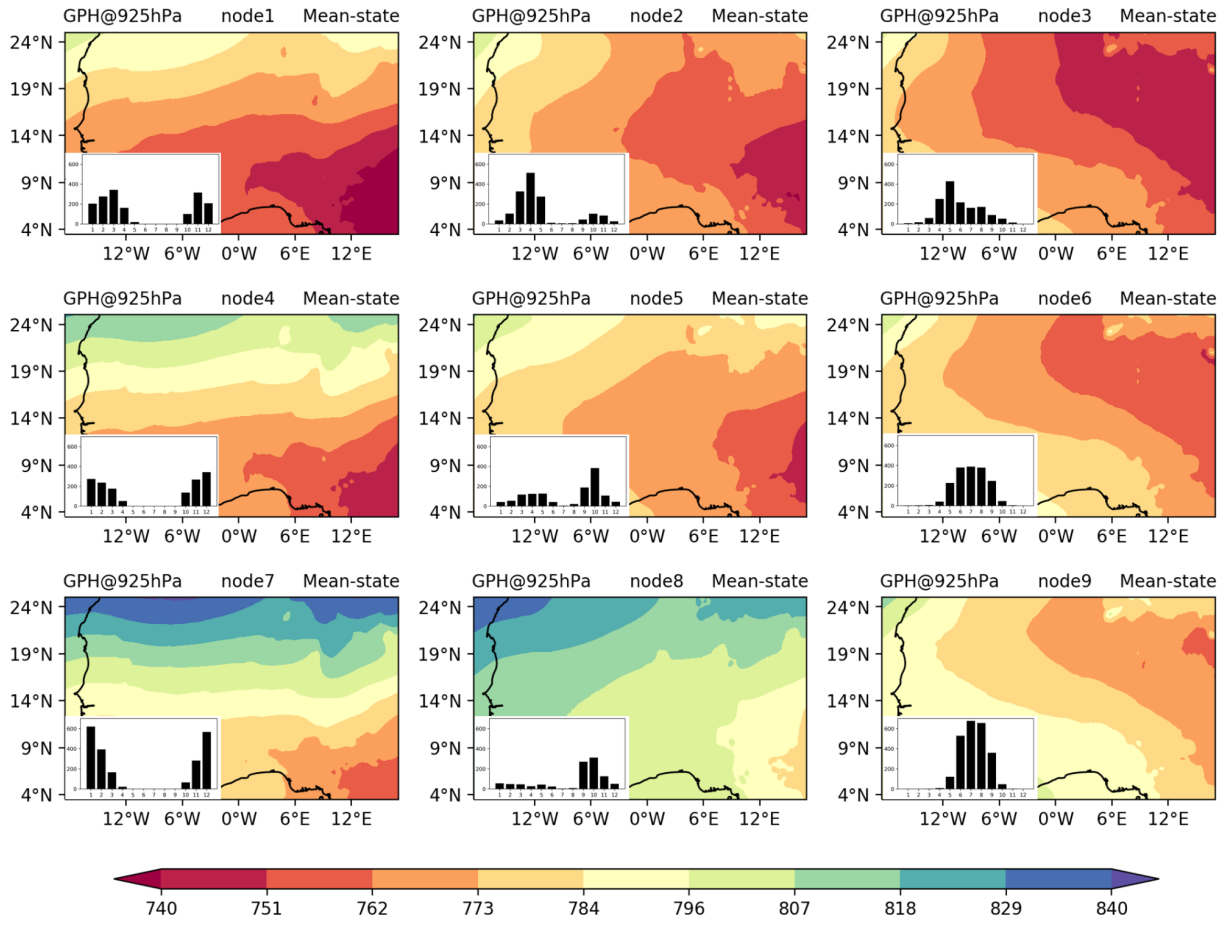

Figure S1. The 3 x 3 SOM using daily ERA5 geopotential height Z at 925 hPa for Western Africa for the period 1981–2020. Insert is the monthly distribution of node cases based on the 3 X 3 SOM analysis

- L167-168: Even if some nodes are ignored, the numbering of the nodes should be as in the full SOM analysis, to be consistent with the complete SOM map.

We made sure the arrangement is consistent with the complete SOM with each node following distribution as in the 9-node case.

- Figure 1: Add the total number of members in each node. Consider normalizing per year and not per month.

This suggestion is respectfully disagreed with, as the purpose of the paper is to develop an understanding of the characteristics of the WAM and its association with MCSs. One of the main characteristics of the WAM is seasonal variability, so normalizing per year will not reveal this variability associated with it. Again, it will be difficult to attain the respective monsoon conditions such as pre-, peak- and post-monsoon when normalized per year.

- Figure 2: Grey grid can be removed to improve visibility. Also, be consistent with X-label intervals. Clarify whether these are daily means or 12 UTC composite.

The grey grid has been removed to improve visibility and the x-label has been made consistent. It has been clarified that they are 12 UTC composite.

- Figure 3: The low correspondence between winds and geopotential heights in the tropical region raises the question: what is the value of classifying by geopotential if it's not indicative of the flow field? Why not directly classify the velocity/ wind-speed fields?

The choice of low-level geopotential height was made in this manuscript because we wanted to consider somehow the influence of the West African Heat Low (WAHL) in influencing instability. At low levels, the geopotential height well describes the strength of the WAHL (Lavaysse et al. 2009; Biasutti et al. 2009). The wind field considered here is the mid-level winds which are consistent with geopotential height in that the mid-level easterly winds follow the northward and southward movement of the heat low.

- L211-218: This subsection is too slim. Either remove it or expand it to get to a conclusion. At the present state, this subsection does not contribute to the main motivation of this study and possibly draws the reader's attention from the main storyline.

This subsection has been removed as suggested.

- Figure 6: This domain should be shown earlier when first presenting the SWA domain.

The domain of SWA has been shown earlier in Figure 2.

- L258: unclear. Why does high humidity lead to cooling?

Thank you for this comment. High humidity does not necessarily lead to cooling. High humidity is just the introduction of more water vapor, which can be in a warmer or cooler atmosphere. The statement on 'enhanced moisture' has therefore been omitted.

- L279: This point was given as a well-known fact in the introduction, so I don't see what is the novelty here.

This point has been removed from this section

- L290: "eastern patterns" – This is not evident in figure 6. This issue should be discussed

Corrected

- L140: "pure node analysis" – What do you mean by this?

This statement has been removed.

Technical corrections

- L25: which=that.

Changed

- L38: variabilities=variability.

Changed

- L42: "Change, 2014" is not a reference, or is missing from the reference list.

Thank you for pointing this out. We have corrected this reference by replacing it with “IPCC 2014”, with its corresponding reference added accordingly as IPCC: Climate Change, 2014: Synthesis Report. Contribution of Working groups I, II, and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Working Team, R.K. Pachauri and L.A. Meyer (eds)]. IPCC, Geneva, Switzerland, 151, 2014.

- L88: environments= parameters?

Replaced ‘environments’ with ‘environmental parameters’

- L97: Is this a correct use of the word stratify? Seems confusing to me. How about grouped/ separated?

Changed. We replaced ‘stratify for’ with ‘grouped into’

- L108: product= data source.

Replaced ‘product’ with ‘data source’

- L126: daily=daily mean.

Added ‘mean’ to ‘daily’

- L182: SOMs=SOM.

Removed ‘s’ from ‘SOMs’

- L200: “much more strengthened” – Rephrase. Consider "Intensified", "Increased" and so on.

Replaced with “intensified”

- L211: “A further” = Further.

Corrected

- L213: during=within.

Replaced

- Figure 4: The term "moving mean" seems more fitting.

Replaced

- L225: This second subtitle is redundant.

Based on the structuring of the results, the analysis has been grouped under various subtitles, of which the second subtitle well describes the analysis beneath it. We would therefore want to leave the subtitle as such.

- L244: Repetitive.

The statement on L244 has been removed

- Figure 7: The colors appear saturated. Expand the color map beyond 2K to avoid this.

The color map has been expanded for figure 7

- L274: observes= demonstrates/ exhibits.

Replaced observes with exhibits

- L290: observe = show/ depict.

Replaced observe with depict

- L308-311: Long sentence, consider splitting.

Thank you for this observation. The sentence has been split to read as follows: “Node 1 climatological conditions depict both, very low initial shear and TCWV. This illustrates the relatively storm-hostile mean conditions for this node, predominantly representing dry season conditions and explaining the low storm frequency of only 0.13 per day.”

- L323: “making node 2…” This sentence is unclear, rephrase.

The sentence has been corrected by removing the last part.

- L330: “This season” – Unclear which season is that.

The sentence has been corrected to capture “this season” as “the monsoon season”.