A Climatological Perspective on Cyclones and Surface Impacts in the Eastern Mediterranean Using Potential Vorticity-Based Classification

Response to reviewers' comments

We thank the two expert reviewers for their careful and constructive comments and suggestions and for acknowledging the importance and novelty of our work. We have addressed all their suggestions in detail below and made the corresponding changes to the manuscript. The main changes since the first submission include:

1. **Substantial revision and clarification of the SOM methodology** - the description of the self-organizing map (SOM) algorithm was expanded to clarify its semi-objective nature and user-defined components. We added a detailed explanation of the configuration, justified the choice of a 2×3 SOM, and included relevant references to previous synoptic studies. An additional appendix figure (Fig. A1) was introduced to demonstrate node similarity and support the robustness of the selected configuration.
2. **Improved physical interpretation of PV–precipitation relationships** - terminology was refined.
3. **Revision of the analysis on precipitation extremes –** we removed the local station-based observational analysis (including associated figures and tables) to maintain consistency with the regional focus of the study and improve the overall coherence and flow of the manuscript. Instead, we added a new analysis of local extremes throughout the domain, adding a second panel to Fig. 6.
4. **Improved geographic clarity throughout the manuscript and figures –** more specific regional references were added.
5. **Substantial revisions to the abstract and overall presentation** - the abstract was shortened and simplified for clarity, and the manuscript was revised throughout for readability, consistency in terminology (e.g., EMCs, SOM terminology), and improved flow, following both major and minor reviewer comments.
6. **A new analysis of the 10-m wind speed anomalies**

In the following we respond to each of the reviewers comments point-by-point.

Reviewer #1:

In this work, Eastern Mediterranean cyclones are separated into six classes based on their upper-level PV patterns over the region. The resulting classes reveal a clear link between upper-level dynamics, seasonality, and cyclone impacts in terms of mean and extreme precipitation and temperature. The study presents a novel and useful categorisation of Eastern Mediterranean cyclones, is well constructed, and is firmly grounded in the existing literature on the topic. I recommend publication in Weather and Climate Dynamics after the following minor revisions are addressed.

General Comments

Reviewer Comment:
Abstract: The abstract would benefit from shortening and simplification. It is relatively long and contains several lengthy, at times convoluted, sentences that could be improved in terms of clarity and readability.
Response:
Following this suggestion, we revised and shortened the abstract.

" Eastern Mediterranean Cyclones (EMCs) are a major contributor to extreme weather in their region, including precipitation, strong winds, cold extremes or dust storms, substantially impacting the population and natural environment. Understanding EMC variability and their associated impacts is essential for improving their predictability and forecasts.

Existing approaches for EMC classification provide limited physical interpretations of cyclone variability. Here we classify EMCs based on their associated upper-tropospheric potential vorticity (PV) structures, providing a novel process-based framework.

Using the self-organising map (SOM) algorithm employed on ERA5 reanalysis we find six distinct PV patterns that highlight different synoptic and precipitation patterns. Characteristics of these clusters are quantified using ERA5 reanalysis and satellite observation.

There are dominant clusters in each season that lead to extreme precipitation and temperatures. We find that there are two clusters, with high PV values over the eastern Mediterranean region, that dominate the eastern Mediterranean's annual precipitation. In addition, we find that a strong ridge upstream of the PV trough affects the precipitation more than the PV pattern with a weak ridge upstream. Also, temperature anomalies during the cyclone passage were found to be strongly linked to upper-level PV patterns, with certain EMC types causing significant near-surface temperature extremes.

The annual frequency of EMCs in some clusters shows contrasting trends, even though the overall frequency of EMCs exhibits no significant trend. If these cluster-specific trends persist, they could lead to an increase in the frequency of less precipitating EMCs, indicating a potential shift toward drier conditions in the region.

Through this classification approach of the upper-level PV distributions we enhance our understanding of the link between EMCs variability and their surface impacts in the region. These findings provide a framework for systematic evaluation of cyclones and their prediction, and may improve strategies for managing the societal and environmental impacts of EMCs at weather and climate timescales. "

Reviewer Comment:

Figure 6: I question the analysis of extremes based on precipitation accumulated and then averaged over such a wide region. In particular when convection plays a role, local precipitation totals can be very high despite relatively modest values of spatial averages over the entire domain. A discussion of this limitation, or an alternative metric that better captures local extremes, would strengthen the analysis. For example, I would suggest applying a similar analysis as this to ERA5 precipitation data, taken by grid-point or aggregated over small (land) regions.

Response:

We thank the reviewer for this insightful comment. We agree that spatially averaged precipitation over a large domain may obscure localized extreme events, particularly those associated with convection.

To address this limitation, we have extended our analysis by introducing an additional metric based on grid-point precipitation. Specifically, we now analyze 24-hour accumulated ERA5 precipitation at the grid-point level, rather than relying solely on 3-day domain-averaged values. For each EMC, we count the number of grid points exceeding different precipitation extremes thresholds (starting from 50 mm/24 h) and construct distributions of precipitation intensity (new Fig. 6b).

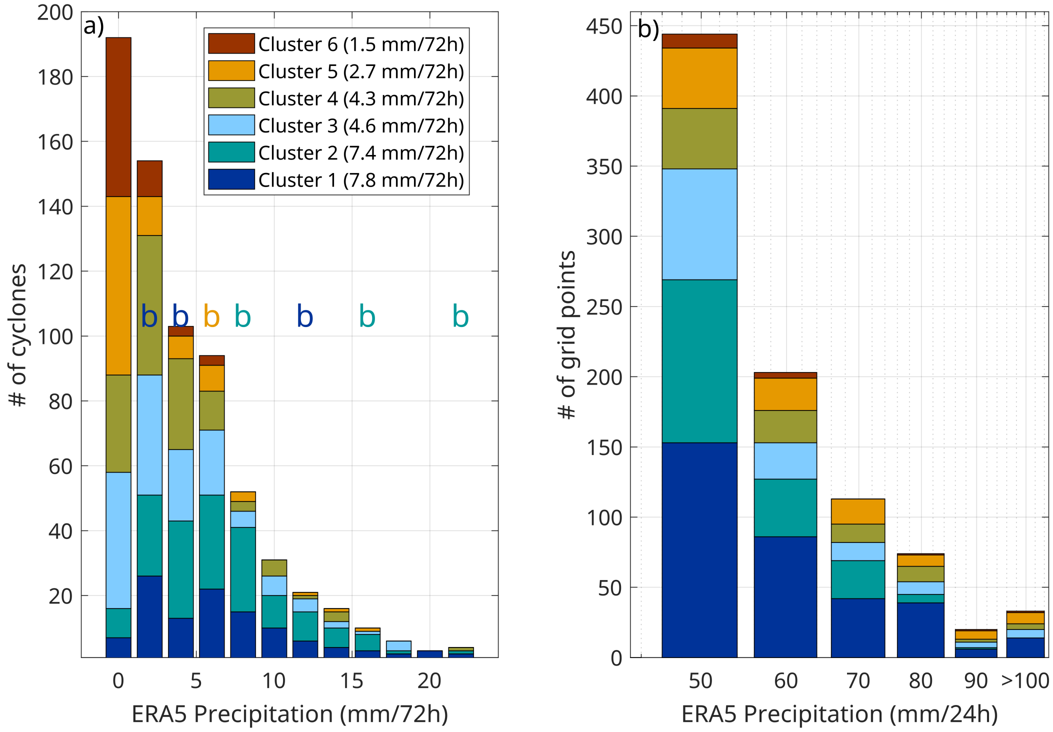

Fig 6: (a) The distribution of mean 3-day ERA5 accumulated precipitation within the domain, per EMC. Bars are grouped by precipitation bins and colour-coded by cluster, with the legend indicating the cluster number and its overall mean grid-point precipitation (mm/72h). The letter b marks explosive cyclones (Bergeron in 12 hours ≥ 1) in their corresponding bins, colored by cluster. (b) Distribution of 24-hour ERA5 accumulated precipitation extremes at the grid-point level within the domain, aggregated over all EMCs. Bars represent the number of grid points exceeding each precipitation threshold, coloured by cluster. All values exceeding 100 mm/24 h are combined into a last single bin.

This complementary analysis allows us to better capture localized extremes and reduces the smoothing effect inherent in spatial and temporal averaging. The results show that, although Cluster 5 is generally characterized by low domain-averaged precipitation, it exhibits a relatively higher fraction of high-intensity grid-point precipitation compared to the other clusters. This indicates that this cluster is more strongly associated with localized extreme rainfall events, which were not fully represented in the original domain-averaged analysis.

We have added a discussion of this limitation and the new analysis in Section 3.4 (Precipitation distribution, variability and extremes), and updated Fig. 6 to include the new panel (b).

Reviewer Comment:
Figure 7 : What is the range of top values in the different stations ? You hint to this in the text in lines 330, but I would appreciated a few more details about the distribution. Also, could you compare these results with a similar analysis applied to ERA5 precipitation data ?
Response:
We thank the reviewer for this comment. Following the comments from the other reviewer and after careful consideration of the role of the station analysis in the manuscript, we decided to remove this section from the revised version. The station observations used in the original manuscript were limited to stations in Israel. While these observations are of high quality and provide valuable local information, their inclusion introduced an imbalance in the spatial representation of the study domain, which focuses on the broader Eastern Mediterranean region. Therefore, we removed the station-based analysis, including Figure 7, from the revised manuscript.

Specific comments

Line 33 : « high » instead of « tremendous ». Generally, I would recommend to limit the use of the word « tremendous » in a scientific context.
Response: revised accordingly

Line 39 : You can add ref to Chiericoni et al. 2025 [1].
Response: We have added a reference to Chiericoni et al. (2025)

Lines 93-101: I suggest using present tense, as in the rest of the manuscript.
Response: Done where needed.

Line 100 : « outside the 5th or 95th percentile range ».
Response: The sentence has been revised accordingly and now reads *"outside the 5th or 95th percentile range."*

Line 135 : Is the choice of six clusters subjectively based on the clustering outcome, or is it based on some metrics as in Givon et al. 2024 (described in Appendix A)?
Response: We thank the reviewer for this important comment. In line with the related remark by Reviewer 2, we have expanded Section 2.4 to clarify how the six clusters were selected. The revised manuscript now includes a more detailed description of the SOM configuration, the rationale behind the 2 × 3 structure, and the criteria used to assess the robustness and interpretability of the classification.

In addition, we have added a new appendix figure (Figure A1) showing the SOM configuration and neighbor similarity structure, which illustrates the variability and relationships between adjacent clusters. This addition provides further transparency regarding the selection of the six-cluster configuration.

Line 164 : I understand what you mean with this sentence, but I find the term « rainy seasons » confusing. Consider rephrasing with the following : « The analysis uses annual periods running from 1 August to 31 July instead of calendar years. »
Response: Done.

Line 175 : I would suggest « support » instead of « substantiate ».
Response: Done

Line 244 : You can refer to [2] to support your statement.
Response: Done

Lines 277-278: Portal et al. 2025, Figure S4 also shows that lightning frequency (i.e., a proxy of deep convection) conditioned on the presence of cyclones is high in the north-eastern Mediterranean in winter. This agrees with the findings described in the following sentence (lines 278-280).
Response: Thank you for this helpful suggestion. We have added a sentence referencing Portal et al. (2025, Fig. S4), which shows that lightning frequency, a proxy for deep convection, is enhanced over the north-eastern Mediterranean during cyclone conditions in winter.

Line 298: I would suggest replacing « a trough extending westward » with « a south-west–to-north-east–tilted trough ».
Response: Done

Line 303: Remove « however ».
Response: Done

Line 390-392: I suggest the use of present tense.
Response: Done

Reviewer #2:

Reviewer Decision
The manuscript should be reconsidered after major revisions.
Reviewer Summary/Narrative
The manuscript aims to diagnose different flavors of Eastern Mediterranean Cyclones (EMCs) by utilizing the self-organizing map (SOM) algorithm. The authors selected a 2 by 3 SOM with 6 nodes to group the EMCs based on PV data. Cyclone trends over time are discussed for the entire dataset as well as for each SOM node. Each node experiences the highest frequency of occurrence during different months throughout the year. Additionally, the different EMC groups have different deepening rates, duration, and distance associated
with them. ERA5 precipitation was compared with IMERG data to demonstrate that the ERA5 precipitation is robust for both large-scale and convective precipitation. Additionally, precipitation by SOM node for observation sites in Israel was examined. The authors do a good job of relating the different SOM node PV patterns to precipitation locations and temperature changes. The end of the manuscript the highlights and importance of each node.
Based on the volume of major/minor concerns listed below, I recommend the manuscript should be reconsidered after major revisions.

Major Comments/Concerns

Reviewer Comment:
1. The authors describe the self-organizing map algorithm as an objective tool to group data, but this is incorrect. The user must specify the number of nodes, specify the shape of the map, the distance function used, and other metrics. This study would benefit from a more in-depth discussion about how the SOM algorithm works as well as quantitative metrics (quantization error, Sammon map, correlation of data to their assigned node, etc.) showing the final map chosen is a good fit for the PV data. Additionally, the labeling of the SOM nodes (not clusters) and using coordinate labeling should be used to be consistent with other studies. The authors also do not cite the SOM algorithm nor reference other studies to show that this is a viable and accepted method for grouping synoptic data.

Response:
We thank the reviewer for this important and constructive comment. We agree that the implementation of the self-organizing map (SOM) algorithm involves user-defined

parameters and therefore should not be described as purely objective. The manuscript has been revised accordingly to clarify that the SOM is an unsupervised, data-driven categorization method that requires specification of the map configuration and training parameters.

In the revised Section 2.4, we now provide a more detailed description of the SOM configuration, including:

- A 2 × 3 rectangular topology (6 nodes)
- Hexagonal topology structure
- Training length consisting of 450 initialization iterations followed by 550 training epochs
- Euclidean distance metric
- Final grid-topographic error of 1.497 PVU

To further justify the selected configuration, we added a discussion explaining that multiple SOM sizes were tested and that the 2 × 3 structure provided an optimal balance between pattern interpretability and over-fragmentation of cyclone types.

Additionally, we have added a new appendix figure (Figure A1) showing the SOM configuration and neighbor similarity structure. This figure illustrates the relationships between adjacent units and demonstrates the topological consistency of the resulting categorization.

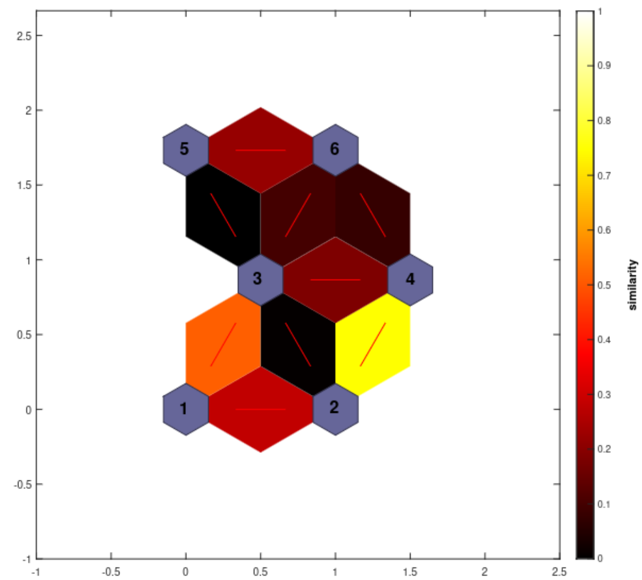

Figure A1: SOM configuration with neighbour similarity, illustrating the differences between neighbouring clusters. Cluster numbers are noted in the purple nodes; note their different order compared to other figures in the paper.

Importantly, each cluster corresponds to a single SOM node. During the development of the classification, several SOM configurations with a larger number of nodes were tested. However, some of these configurations produced nodes with very similar structures and low variance between them, which effectively merged into patterns comparable to the six-cluster solution adopted here. Regarding terminology, we acknowledge that within strict SOM methodology the term “nodes” is standard. However, studies focusing on Mediterranean cyclone classification commonly use the term “clusters” when referring to SOM-derived categories. To maintain consistency with existing Mediterranean literature while preserving methodological clarity, we now clarify in Section 2.4 that the six SOM units (nodes) are hereafter referred to as clusters for consistency with regional synoptic classification studies.

We have also added a citation to the original SOM formulation (Kohonen, 1982) and included references to recent synoptic applications of SOM classification (Larson et al., 2025; Baiman et al., 2023; LaChat et al., 2024; Givon et al., 2024) to demonstrate that this is a well-established and widely accepted method for synoptic-scale pattern analysis.

Reviewer Comment:
2. More geographic specificity in the text and in figures would help clarify the results and orient the reader.
Response:
More specific regional references were added.

Reviewer Comment:
3. It is unclear why observational data for only Israel was used instead of everywhere within the study domain. Since this is only for a small portion of the domain, I think that observational data for the entire domain should be shown or this section should be omitted because it breaks the flow of the manuscript.
Response:
We thank the reviewer for this thoughtful comment. Upon reconsideration, we agree that the inclusion of station observations from Israel alone may disrupt the broader regional focus of the manuscript and create an imbalance in spatial representation across the study domain.

Expanding the observational component to the entire Mediterranean region is unfortunately not feasible. We decided to remove this section, and replace it with an alternative analysis of local extremes, also considering concern raised by the Reviewer #1 (new Fig. 6b and accompanying text).

Reviewer Comment:
4. To better connect the PV SOM patterns to the precipitation, this study would benefit from including an additional figure (and small section) that provides additional information about forcing mechanisms and moisture availability. A figure showing mid- or lower-level ascent and total column water vapor will aid the description about lee precipitation, “drier” nodes, large-scale vs convective precipitation. Some nodes were described as “drier,” but I do not think that you can say that from precipitation alone. Rather, those nodes show a “lack of precipitation.”
Response:
We thank the reviewer for this constructive and helpful comment. We agree that the term “drier” may not have been the most appropriate wording in this context. Following your suggestion, we revised the manuscript and replaced this wording to directly refer to precipitation which more accurately reflects our focus.

Motivated by the reviewer's comment, we further examined the moisture availability directly. As shown in Fig. R1 below, clusters 5 and 6 are indeed characterized by relatively high total column water vapor (TCW) aligned with their occurrence in the warm seasons. We also investigated the dynamical forcing using QG diagnostics (Fig. R2). This analysis indicates that the reduced precipitation in clusters 5 and 6 is primarily related to weaker or absent ascent, rather than a lack of moisture. In the revised manuscript we added a sentence: "Despite the reduced precipitation, additional analysis indicates that these clusters are characterized by relatively high total column water (not shown), consistent with their occurrence during the warmer seasons. This suggests that the limited precipitation is not associated with reduced moisture availability, but rather with a lack of sufficient dynamical forcing to initiate precipitation. Consistent with this interpretation, quasi-geostrophic diagnostics (not shown) indicate relatively weak large-scale ascent in these clusters."

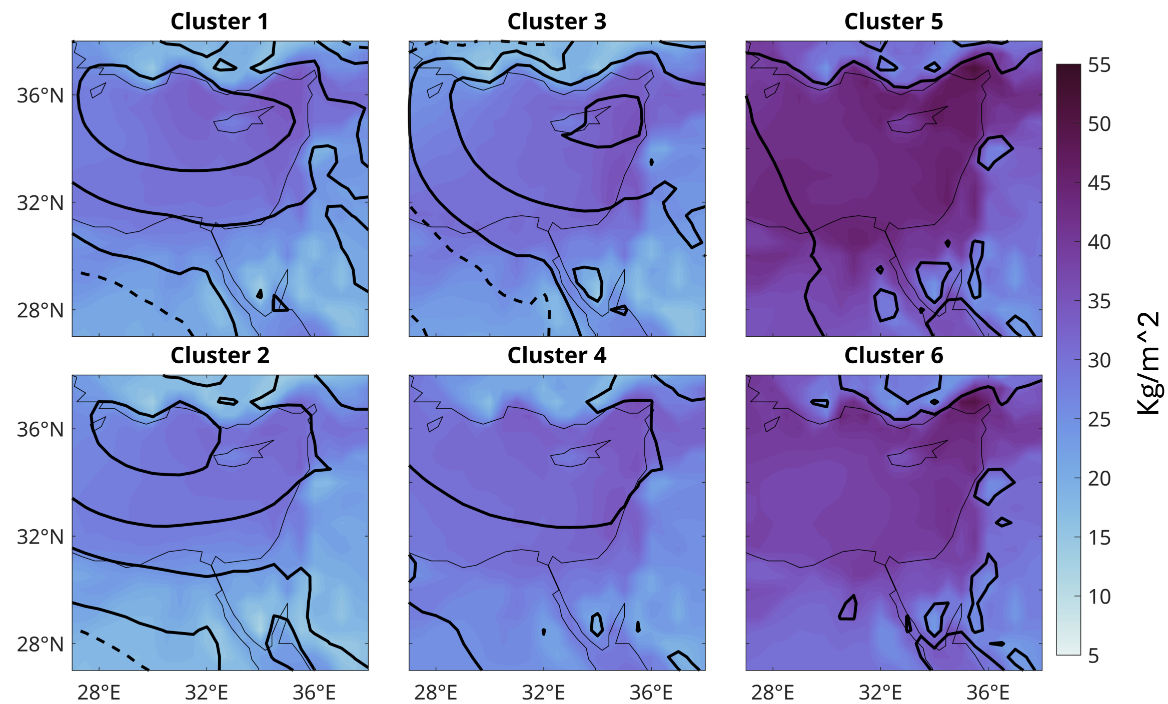

Figure R1: Composite column-integrated water vapor between 1000 and 500 hPa for each cluster.

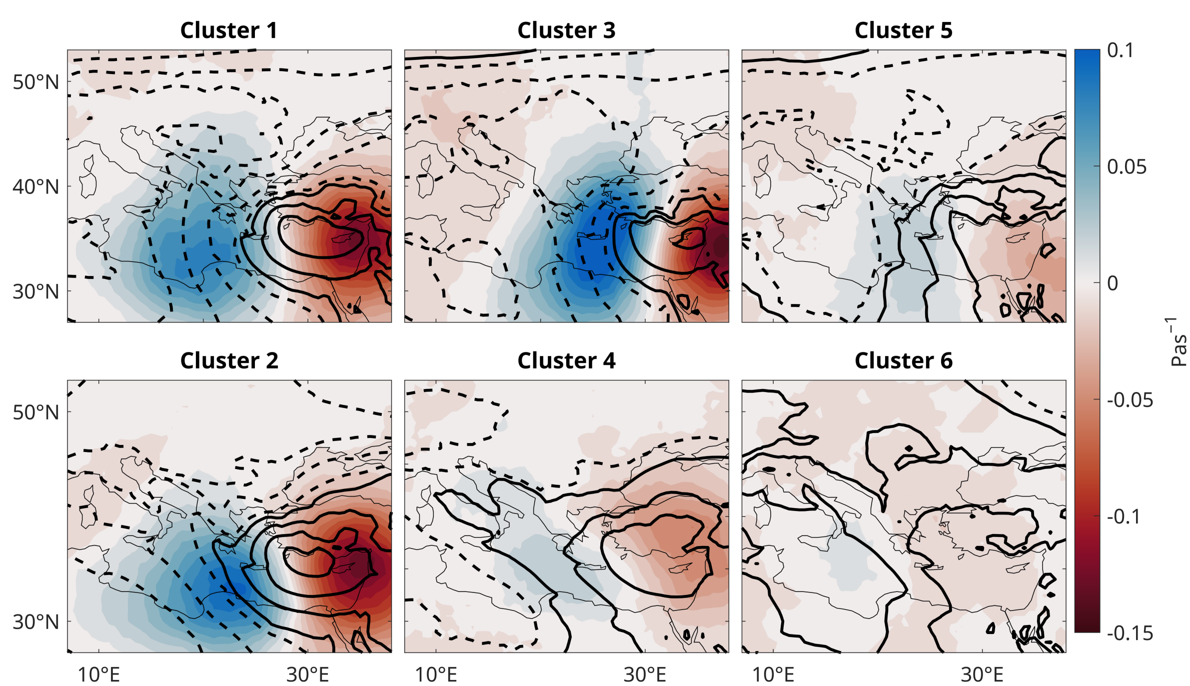

Figure R2: Composite QG omega at 700 hPa for each cluster.

Reviewer Comment:

5. Given that the authors motivate this study by discussing how these EMCs cause many surface impacts, I believe that a discussion of the winds associated with these EMCs would be beneficial. If the authors only want to focus on precipitation and temperature changes, then that should be clearly stated in the introduction.

Response:

We thank the reviewer for this helpful suggestion. In response, we have added a new analysis of the 10-m wind speed anomalies in Section 3.6 (Fig. 8). This addition describes the spatial distribution and intensity of near-surface winds across the different clusters, as well as their relationship to the composite SLP fields.

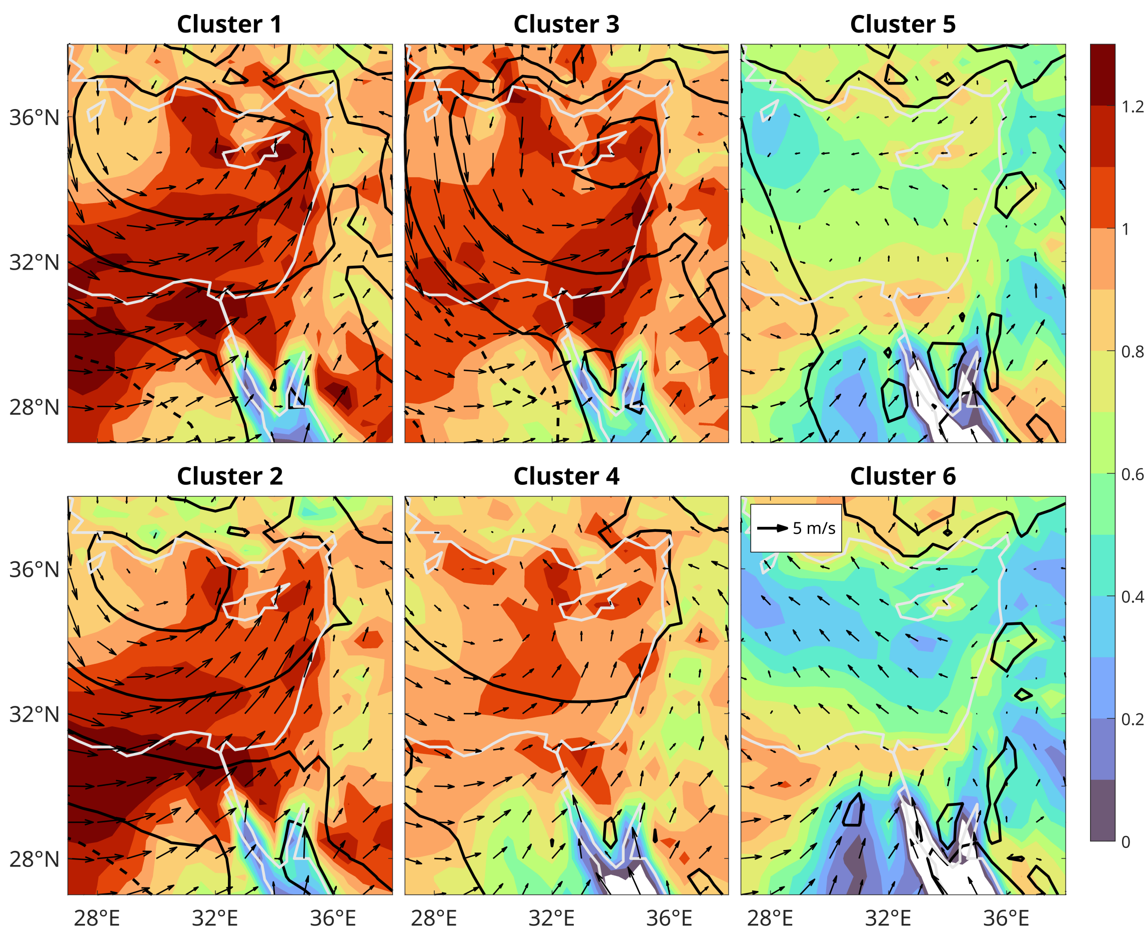

Fig 8: Composite of 10-meter wind speed anomalies normalised by standard deviation representing by shading, computed as the difference between the cluster-mean wind

speed and the climatological monthly mean divided by standard deviation (negative values are white).
Arrows indicate the composite vector wind anomalies from the monthly mean climatology(U and V components). SLP composites is shown in black contours at 2-hPa intervals (dashed over 1015 hPa)

Specific Minor Comments and Line-by-line Edits

ABSTRACT

L2: recommend not using the word “significantly” unless using it for statistical reasons
Response: Addressed. The wording was revised to remove “significantly.”

L4: “EMC” should be “EMCs.”
Response: Corrected.

L7 & L20: “impacts” is often mentioned throughout the manuscript, but what are specific examples of these impacts?
Response: The text was revised to clarify examples of the impacts associated with EMCs.

L8 & throughout the manuscript: “Self-Organizing Maps” should not be capitalized (“self-organizing maps”). Also, this “maps” should not be plural. I would recommend saying “Using the self-organizing map algorithm to categorize ERA5 data into 6 distinct PV patterns that highlight different synoptic and precipitation patterns.”
Response: Corrected.

L14-17: break this sentence into two sentences for easier readability
Response: The sentence was revised for improved readability, in line with this and other reviewer comments requesting simplification of the abstract.

1 INTRODUCTION

L32: what is a compound event?
Response: Clarified in the text that a compound event refers to **multiple hazards occurring simultaneously**

2 DATA AND METHODS

L89: add “by” in between “(SLP)” and “employing” and change “, and” to “to”
Response: Corrected.

L94: why is the ERA5 data interpolated to 0.5 degree from the native 0.25 degree horizontal Resolution?
Response: The ERA5 data were interpolated from the native 0.25° resolution to 0.5° primarily for data-storage constraints.

L110: why only use observations from Israel? This should be explained earlier in the motivation of the study.
Response: This section has been removed from the revised manuscript, as discussed in the response to the major comment.

L121: more discussion about how the 10 cyclone-tracking differ would be beneficial. What are their strengths and weaknesses? What variables do they use to classify the cyclones?
Response: There is a reference to the detailed comparison presented in the cited study: **https://wcd.copernicus.org/articles/4/639/2023/**

L126: making Fig. 1b its own figure placed after this paragraph would introduce the domain better and make the manuscript flow better
Response: We appreciate the reviewer’s suggestion. However, we chose to keep the current figure placement, as Fig. 1b is already referenced at the appropriate point in the text.

2.4 SELF-ORGANIZING MAP (SOM) CLASSIFICATION

Subsection title: I would recommend changing “classification” to “algorithm”
Response: Title revised.

L132-133: A reference to the original Kohonen 1982 algorithm should be added here.
Response: Added.

Acknowledging the MathWorks SOM package can be moved to the acknowledgment section.
Response: The acknowledgment of the MathWorks SOM package was moved to the Code Availability section**.**

Additionally, more discussion about how the SOM algorithm spatially groups data

should be added. To further justify why the SOM algorithm is an appropriate tool to use for this study, I would recommend referencing other synoptic studies that utilize this algorithm, such as Larson et al. 2025, Baiman et al. 2023, and LaChat et al. 2024. These articles are good examples of how to describe the algorithm.
Response: Additional explanation of the SOM algorithm was added, along with these references.

L133: throughout the manuscript, there are inconsistencies when referring to the EMCs. Since the EMC acronym is introduced, I would recommend replacing all instances of "cyclone" with "EMC." Additionally, saying EMC "member" seems unnecessary.
Response: The terminology was revised throughout the manuscript for consistency.

L134: Stating that "six clusters were found" is incorrect. The 6 SOM nodes were chosen by the user. In the context of SOM studies, the word "cluster" is commonly used when different SOM "nodes" are grouped together to help describe the scientific results.
Response: We clarified the description of the SOM configuration and added an explanation about the chosen 2×3 SOM structure. (see more detailed response in the response to the major comment)
The term **cluster** was retained because it is commonly used in Mediterranean cyclone classification studies.

Alternatively, you could say: "A 2 X 3 SOM (6 nodes) was used for this study." Additionally, more explanation as to why only 6 nodes were chosen, as well as why a rectangular and non-square SOM was used. What type of topology was used, what neighborhood function, what distance metric?
Response: A more detailed explanation of the SOM configuration was added to Section 2.4.

L135: Were there any subtle differences when utilizing more SOM nodes? While the PV maps may not look very different, are there notable differences in precipitation and temperature anomalies? Using a SOM is a great way to pick out subtle differences, but that can be difficult if you have too few nodes.
Response: We thank the reviewer for this insightful comment. During the early stages of the analysis, we tested several SOM configurations with different numbers of nodes. Increasing the number of nodes indeed produced additional patterns; however, many of these nodes were very similar to one another and did not provide additional meaningful

information regarding the relationship between the upper-level PV structures and the associated surface impacts.
In practice, increasing the number of nodes also reduced the number of EMCs assigned to each node. This resulted in smaller sample sizes per node and therefore reduced the robustness of the composite analyses of precipitation and temperature anomalies. For this reason, we selected a 2 × 3 SOM configuration (six nodes), which provided a good balance between capturing the main variability in PV structures and maintaining sufficiently large samples within each node for reliable statistical interpretation.
This clarification has now been added to Section 2.4 of the manuscript.

L139-149: While it is good that you ran the SOM algorithm on the data multiple times, it would also be useful to discuss other metrics (that are not subjective) to show that the 2 by 3 SOM is a good choice for this data, such as the quantization error the correlation of the different maps to their categorized SOM node.
Response:
Thank you for this important suggestion. To further support the choice of the 2 × 3 SOM configuration (6 nodes), we examined the quantization error as a function of the number of nodes (elbow method, see Fig R3). The results indicate a gradual decrease in error with increasing node number, without a sharp minimum, suggesting that multiple configurations could reasonably represent the data.

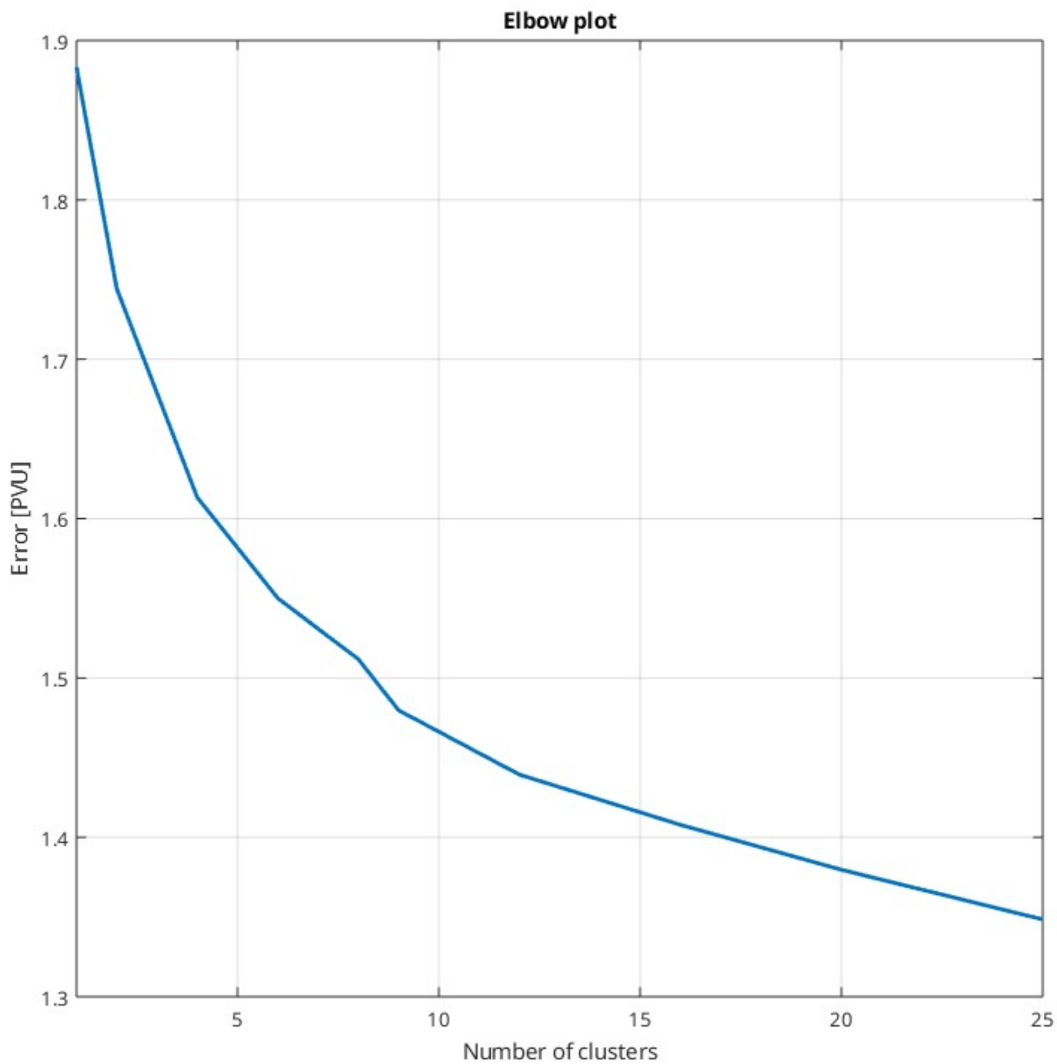

Fig R3: Elbow plot showing the relationship between the number of clusters and the quantization *error (PVU).*

Therefore, the selection of six clusters was guided not only by this objective metric but also by physical interpretability and prior knowledge of upper-level PV structures in the region. Six clusters were found to represent distinct and recurring PV patterns corresponding to meaningful upper-level atmospheric states.

Increasing the number of clusters does not reveal substantially new patterns, but rather subdivides existing ones, reducing the robustness and interpretability of the impact analysis. Conversely, using fewer clusters (e.g., four) leads to merging of physically distinct patterns (e.g., Cluster 3 with Cluster 1, and Cluster 4 with Cluster 2), which obscures important differences in EMC impacts, as well as characteristic gradients and structures in the PV fields.

2.5 CYCLONE DEEPENING RATE

L152-153: Can you quantify short vs long tracks?
Response: Clarification added based on the climatological discussion in:
Objective climatology of cyclones in the Mediterranean region (Trigo et al., 1999).
https://journals.ametsoc.org/view/journals/clim/12/6/1520-0442_1999_012_1685_ococit_2.0.co_2.xml
Cyclones in this region may last **less than 12 hours**, considerably shorter than the typical **3–3.5 day lifetime** of North Atlantic or North American systems.

2.6 SIGNIFICANCE OF THE TRENDS

L165: Is the rainy season DJF? A clarification in parenthesis would be beneficial
Response: The sentence was revised (also following Reviewer 2's suggestion): "The analysis uses annual periods running from 1 August to 31 July rather than calendar years."

Also, I want to make sure I understand this correctly, the 1979 and 2020 EMCs are included, but
are they just not used for the MK trend analysis ?
Response: Yes, this is correct.

3 RESULTS

3.1 CYCLONE CHARACTERISTICS

L169: Is there a duration requirement for how long the EMCs persist within the smaller study domain?
Response: No duration requirement was imposed.

3.2 SOM CLASSIFICATION

L177: SOM groupings are not "revealed" they were "chosen" by the user
Response: Text revised.

L178: You can talk about how the neighboring nodes share similar PV distributions because the SOM is useful for spatial data and showing spatial relationships. Again, say "nodes"
instead of clusters.
Entire manuscript: label SOM nodes with [row #, column #] instead of saying "cluster #." This is consistent with the SOM literature and makes it easier for the reader to visualize the SOM as it is being described in the text.
Response: Regarding terminology, we acknowledge that within strict SOM methodology the term "nodes" is standard. However, studies focusing on Mediterranean cyclone classification commonly use the term "clusters" when referring to SOM-derived categories. To maintain consistency with existing Mediterranean literature while preserving methodological clarity, we now clarify in Section 2.4 that the six SOM units (nodes) are hereafter referred to as clusters for consistency with regional synoptic classification studies. (see more detailed response in major comment)

L182: Add "a" between "and" and "less".
Response: Corrected.

L183: Replace "members" with "EMCs" and only have "22%" in the parentheses. Ensure this is consistent throughout the manuscript.
Response: Corrected.

L186: For node 6, there is still yellow PV shading which indicates that the PV values are still of the same magnitude as the other nodes. Consider revising the sentence with more specific geographic references.
Response: Sentence revised to include clearer geographic references.

L193-194: Have you already created EMC-centered composites? I think that would help clean up a lot of the noise that can be seen in the figures.
Response: In Givon et al., Mediterranean cyclones are grouped and subsequently analysed using cyclone-centered composites. In the present study, however, we intentionally adopt a geographically fixed framework over a defined Eastern Mediterranean domain. This choice allows us to explicitly examine the relationship between cyclone-related upper level PV structures and the regional topography and land-sea contrast which are key for cyclone development in the region.

3.3 SEASONALITY

Fig. 3: I found it fascinating that each SOM node features a different month with its highest frequency of occurrence. To improve communication of these results, you could create histograms like Fig. 1c for each SOM node. That way, the reader can connect back to the spatial relationships between SOM nodes.
Response: We considered the reviewer's suggestion (Fig. R4), but retained the existing figure as it allows easier comparison of seasonal variations between nodes.

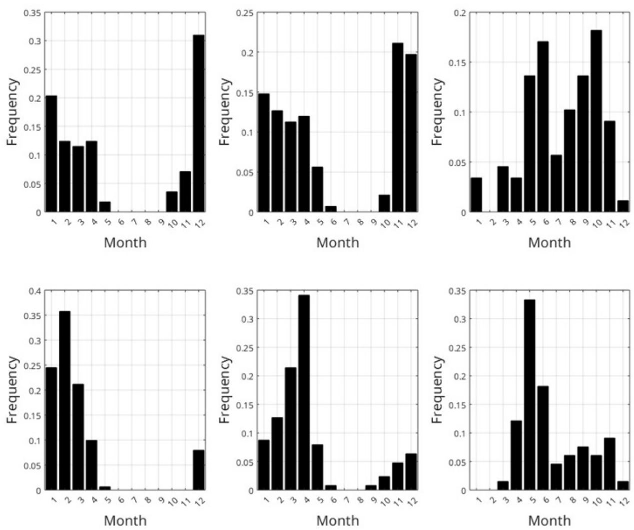

Fig. R4: As Fig. 1c in the manuscript, but separated by SOM nodes.

L209: Add "…as winter progresses into spring," especially because node 4 EMCs occur the most frequently in April.
Response: Added.

L216-236: I liked how you added the numerical values that describe the EMC distance when referenced throughout the text (for example, L219). I think it would also help the reader if you did that for the deepening rates and duration.
Response: Added where it strengthens the message.

L220: Adding a figure that shows EMC tracks for each SOM node would further support this statement as well as complement Table 1.
Response: Figure R4 shows EMC tracks for each SOM node. As each cluster contains a large number of trajectories, the resulting plots are very dense and visually cluttered, making it difficult to add useful information in our view.

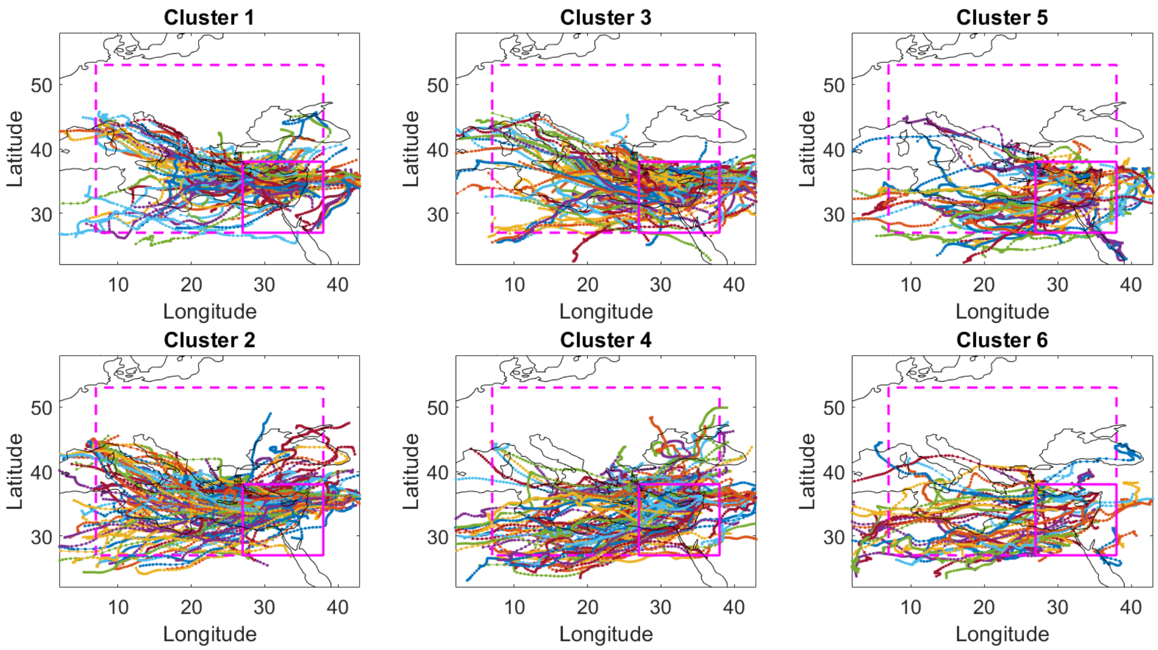

Figure R5: Cyclone tracks grouped by cluster. Each panel shows all tracks assigned to a given cluster with random colours.

L229: This paragraph could go with the previous, unless a transitionary sentence is added to the start of it.
Response: merged.

L230: "Sharav" does not need to be in quotes.
Response: Quotes removed.

Table 1: A mention of these values being the average values for the EMCs in each node would help clarify this table and caption.
Response: this information is mentioned in the table caption which is rephrased in the revised manuscript.

L244: Well done mentioning that this is important for assessing surface impacts.
Response: Thanks.

L247: I like the specific geographic features and regions mention here, please do this more throughout the manuscript (instead of saying domain).
Response: Thanks, done.

Other thoughts: A sentence discussing how the IMERG data compares in regions with convection dominated ERA5 precipitation would be a good benefit to the paragraph starting on L256.
Response: Thanks, done.

L266: Remove "significant" and listing the types of precipitation hazards with strengthen this paragraph.
Response: done.

L288: "The fact that" and "interesting" can be removed from this sentence to be more concise.
Response: done.

L294-295: This is a great connection, and you can also mention that this can also be seen in Table 1.
Response: done.

L301: Refer back to Fig.2
Response: done.

Other thoughts: A figure that shows mid-level ascent/descent as well as moisture availability would further support the connection between the PV SOM nodes and the observed precipitation.
Response: please refer to the response to the major comment.

3.4 PRECIPITATION DISTRIBUTION, VARIABILITY, AND EXTREMES

L319: Since moisture availability is not shown for the nodes, I am not sure if saying that a node "drier" is the best way to describe a node with less precipitation.
Response: Done.

L324: abrupt change to talking about localized precipitation in Israel. Maybe start a new Subsection?
Response: This section has been removed**.**

Figure 7: As someone not as familiar with the geography of Israel, could you add more geographic information (cities, topographic contours, etc.) to orient themselves?
Response: This figure has been removed**.**

L332: Stating that “Cluster 5 extremes dominate southern Israel” is too generalized given that there is only one observation site there.
Response: This section has been removed**.**

Table 2: I am struggling with understanding this table. What are rank-1, rank-2, and rank-3? Why don’t all of the values in a column add up to 60? The explanation in the caption would benefit from improved clarity.
Response: This table has been removed**.**

L368-373: When reading the previous paragraph, I had questions about if showing the +12 hr plots were just showing diurnal patterns, so I am glad you addressed the consistency of these patterns in this paragraph!
Response: Thanks**.**

3.6 OBSERVED CYCLONE FREQUENCY TRENDS

Note: This section may be best located after the initial SOM is introduced.
Response: Presenting the trend analysis at this stage allows the reader to more easily connect the observed trends with the cyclone characteristics described earlier in the manuscript.

L380: Can you also include the m-values in Fig. 1a like you did in Fig. 9 to support this Statement?
Response: In this case the value is **0**, so it was not included.

Figure 9: Awesome figure!
L384: I really like this sentence.
L386-388: Yes!
Response: Thanks**.**

Other note: Why do you think there is such an oscillation pattern for Cluster 5? It is almost interdecadal. Maybe ENSO? Curious about what you think of this.
Response: We also noticed a possible oscillatory behavior in the Cluster 5 time series,

with an approximate periodicity of ~5.8 years. However, the correlations we obtained were relatively weak and did not provide robust evidence of a clear relationship with known climate modes. In addition, investigating the potential drivers of this variability is beyond the scope of the present manuscript. Therefore, we decided not to pursue this interpretation further in the manuscript.

4 DISCUSSION AND CONCLUSIONS

Figure 10: What do the different colors on the upper panel represent?
Response: The colors in the upper panel represent the different clusters and follow the standard color scheme used throughout the study. The choice of colors is intended to convey the general "feeling" of each cluster. For example, deep blue tones are used for winter, strongly precipitating cyclones, while warmer colors represent more summer-like systems, which are typically weaker and associated with warmer conditions.

L391: "grouped"/ "categorized" may fit better than "classified"
Response: done.

L393: More discussion about temperature anomalies would benefit this list. I like how you also talked about significant trends in Cluster 5, I think it would be great to do that for each Node.
Response: While some nodes show indications of variability, Cluster 5 is the only node that meets the stronger statistical significance criterion used in this study. For this reason, we chose to focus the discussion on Cluster 5, in order to avoid overinterpreting weaker signals in the other nodes that do not meet this threshold.

L424: If the goal of this manuscript is to provide generalized information about EMCs to forecasters, then I actually think that EMC-centered composites would be more beneficial. Centered composites would provide clearer signals that forecasters can think about and use to improve their forecasts.
Response: In Givon et al. (2024), Mediterranean cyclones are grouped and subsequently analysed using cyclone-centered composites. In the present study, however, we intentionally adopt a geographically fixed framework over a defined Eastern Mediterranean domain. This choice allows us to explicitly examine the relationship between cyclone-related upper level PV structures and the regional topography and land-sea distributions.

L430-432: I disagree. There needs to be a discussion about the subjectivity of choosing how
many SOM nodes and the structure of the SOM.
Response: We have added a sentence in the manuscript addressing the subjectivity in selecting the number and structure of SOM nodes.

Other note: The localized precipitation in Israel was not discussed in this concluding section—is this supposed to be a key part of the manuscript?
Response: This section has been removed from the manuscript.