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Comment on esd-2022-24

Anonymous Referee #2

Referee comment on "Vb-cyclones and associated North-Western Mediterranean Sea state in regional coupled climate simulations: evaluation and projection" by Praveen Kumar Pothapakula et al., Earth Syst. Dynam. Discuss.,
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Review of "Vb-cyclones and associated North-Western Mediterranean Sea state in regional coupled climate simulations: evaluation and projection" by Pothapakula et al.

This study aims to understand future projections of Vb cyclones that are often associated with extreme precipitation and floods in three catchments in central Europe. By analyzing coupled downscaled simulation from ERA-20C reanalysis (for evaluation) and EC-EARTH (both historical and future runs), links between potential drivers of Vb cyclones and their associated precipitation are explored in the northwest Mediterranean Sea, namely, SST, evaporation and wind speeds. While the aim of the study is obviously both scientifically important and relevant, it is unclear what the coupling adds to the already large body of literature on the topic. It is also not clear if the current modeling setup and methodological approach are able to address the research aims adequately, given the large cold biases that are introduced by the driving GCM, and the lack of more careful attention to the hypothesized mechanisms linking the different variables upstream and the resulting precipitation (that may require, e.g., time lagged analysis). I detailed below on specific issues that exemplify these concerns, which, unfortunately mean that I recommend to reject the paper from being published in ESD.

In addition, the manuscript is poorly written, with numerous grammatical errors and lack of clear storyline connecting the sentences and paragraphs. Also beyond the language itself, the text often mentions the results in a too minimal sense, without interpretation in light of the research goals. A major rewriting is required before specific suggestions can be pointed out regarding the language.

Major issues

1. The introduction is not coherent and does not provide the reader with the motivation for the work. In fact, I was left wondering what are the goals of this study? At the end of the introduction I assumed that the study aims to understand the connection between NWMS SST/evaporation and Vb cyclone occurrence and its associated precipitation in future projections. However, this goal is not specifically mentioned as one of the three aims in the end of the introduction, and the "process chain" also remains too vague at this stage. Moreover, there are many knowledge gaps that emerge from the cited literature, but the authors do not put a focus on them, so it remains unclear which gaps will be eventually addressed. For example, (i) Krug et al. (2022) found ~10 Vb cyclones per year (and stated that this is consistent with reanalysis), while Messmer et al. (2020) found less than 3 cyclones per year in both present and future simulations. (ii) the process chain relates sea state with Vb cyclones and precipitation. However, Krug et al. (2022) found that Mediterranean evaporation plays a marginal role in Vb cyclones-associated precipitation. Are any of these gaps going to be addressed by the current study? (iii) the seasonality of Vb cyclones and its changes is not clear (summer noted as the peak in line 27 and spring in line 33).

2. Methodology section and the "process chain":

- The rationale for the focus on the NWMS region SST, evaporation and wind is not clear, given the insignificant role of this region as a moisture source found by Krug et al. (2022).

- The "process chain" is not immediately clear from the introduction and needs to be clearly explained before the method from information theory is described. Do the authors refer to effects of SST or its gradients on cyclone intensification or on thermodynamical processes feeding precipitation? Or both? Such a core issue in the manuscript must be clearly outlined and motivated, which is currently not the case.

- lines 170-174: precipitation is averaged in the different catchments during the Vb cyclone track lifetime. However, precipitation falling in the catchment during this whole time cannot be directly attributed to the cyclone, especially if the cyclone is still far. Thus, this approach needs to be justified.

- lines 198-203: it is not clear how the process chain can be studied by considering the mixing of all Vb cyclone days, i.e., without referring to the time evolution, and hence the processes in question which describe a system evolving in time. What is the meaning of $\omega=1$ (units?)

- line 203: what is the Granger causality?

- line 204-205: what did Krug et al. (2021) find and what is the current study doing differently?

- lines 234-246: this important statement needs justification, as we know that e.g., upper tropospheric troughs and their lower tropospheric cyclonic organization typically govern evaporation on their rear side and precipitation ahead, at the same time, therefore undermining the applicability of this method.

3. Results: Vb cyclone occurrence:

- the two historical simulations demonstrated huge biases in the seasonal distribution of simulated Vb cyclones, with 41% underestimation of winter events, and 49% overestimation of summer events in the historical simulation, compared to the evaluation simulation. This remark is left without further discussion, but it strongly undermines the validity of the future simulation results. Summer Vs. winter cyclones are expected to be dynamically different in terms of governing mechanisms and associated precipitation (see, e.g., recent review Flaounas et al. 2022). The different seasonality likely affects some of the differences observed in Fig. S3, as summer cyclones may be shallower, as noted in line 272, however this can be easily checked, rather than noting that it 'might be attributed...'

Flaounas, E., Davolio, S., Raveh-Rubin, S., Pantillon, F., Miglietta, M. M., Gaertner, M. A., ... & Ricard, D. (2022). Mediterranean cyclones: Current knowledge and open questions on dynamics, prediction, climatology and impacts. *Weather and Climate Dynamics*, 3(1), 173-208.

4. Results: precipitation, SST, evaporation:

- Fig. S7 and accompanying text: the systematic bias of the historical simulation is not mentioned in the text. Is it related to the bias in Vb cyclone density (Fig. S2)?

- The text related to Fig. 3 does not discuss the variation of SST with ranked precipitation, beyond the slight negative anomalies for the high ranks. The figure is left simply there, but no description or interpretation are provided.

- are there trends or large variations in the SST climatological values that is subtracted to

produce the anomaly graph for each simulation period? If so, are they reflected in the anomaly results of Fig. 3? How is the different seasonality affecting the result (STD of SST likely varies with season).

- Fig. 4 and accompanying text: does the historical-evaluation difference relate to the seasonal bias? Or to cyclone location differences? These aspects can and should be checked, rather than simply stated.

- line 318: unclear which process linking negative SST anomalies and precipitation the authors refer to. What do we learn from the results shown in Fig. 5 about the process chain?

- lines 324-328: the notion contradicts the findings in Krug et al. (2022).

- Generally in this section when discussing Figs. 4, 7, 10, S8, S9, S10 it is unclear if/how the authors relate to significant biases, comparing the two historical simulations, when interpreting the future simulation? If major biases exist, also with regard to the information exchange (Figs. 5,8), what credence do we have for the future projection?

- lines 355-362: what is the underlying process chain? It is unlikely that the newly-evaporated moisture feeds the precipitation directly, as there is no time lag between the two, and these are separate airmasses. It seems more likely that both winds speeds/evaporation and precipitation are in turn affected by the intensity of the cyclone itself.

- lines 376-377: what process links wind speeds in the NWMS and precipitation in the catchments? How do the authors interpret the similar information transfer among simulations despite the differences in SST and evaporation signals, if the process assumed connects wind speeds to evaporation, which in turn reduces SST and increases precipitation?

5. conclusions:

- There is missing reference to past literature mentioned in the introduction which found different results regarding the future projections of Vb cyclones and their precipitation, and a deeper explanation as to why this may be.

- relation between NWMS variables and precipitation: again it is not discussed what can be

concluded from a simulation which already does not pass the evaluation step in terms of relationship of the variables (representing some mechanistic understanding, see also major point #2). Do we trust the mostly insignificant future changes given the large biases in the historical simulation, and the large SST biases of EC-EARTH driving model?

- the relatively good agreement between the historical simulations in terms of cyclone numbers in contrast to the very large biases in terms of the variable correlations, suggests that overall they may not be critical to estimate the "right" frequency? This is not further discussed.

Minor comments

Line 31: missing reference to the 4-10 numbers

line 167-169: which box plot is it referred to?

line 175: it is confusing that the uptake region is defined only later in line 180

line 250: the trends for each period are not significant, but the authors do not mention here if there is a statistically significant difference between the historical and future simulations?

Line 253: Fig. S1 should contain also the overall mean numbers and STD, rather than showing only the interannual variability which does not contain relevant information if the trends are not significant. Are any of the seasonal-dependent trends significant? (e.g., summer in the evaluation simulation? Is a similar trend observed in reanalysis?)

Line 254-256: this statement needs supporting evidence. High SST is not known to often support the occurrence of Mediterranean cyclones.

Line 260: this is inconsistent with Messmer et al. (2020) mentioned in the introduction (line 60).

Line 402: change '2006' with '2045'.

Figures:

Fig. S2: missing units

Fig. S4: too small titles, typo in "autumn"

Figs. 2 and S5: since the aim is to contrast simulations, I suggest to separate the panels by catchments, and plot the different simulations for each.

Fig. S6: a logarithmic scale for the y axis should make the lines more distinguishable.

Figs. 3, 6, 9: mark the +0.75C and +1.5C lines for SST in Fig. 3 and the other constants in Fig. 6, 9 for serving as a clearer reference.

Figs. 4, 7, 10, S7, S8, S9: I don't understand these plots. If these are maps of precipitation/evaporation/SST or wind speed anomalies in the domain during Vb cyclone days (unclear if any lag considered?), then they don't refer to the specific catchment. Is this why the 3 columns look ~identical?