

Responses to Reviewers for the manuscript:
“On the Marine Cold Spells in the Mediterranean Sea “ by Darmaraki et al.,
July 2026

Replies to Reviewer 1:

Summary

The authors start with a thorough and interesting review of known MCSs that have occurred in the Med, what their physical drivers were, and if they had any bio/ecological impacts. They then show the validation of their model against satellite observations. With an issue being that the authors use MLT from the models, but SST from satellite obs. This mismatch is acknowledged, but not much more is said about it before going into the results on the future MCS state in the Med. Using both fixed and moving baselines, the authors show what the current/historic forcing of MCSs in the mixed layer have been, and what they may become. Interestingly, regardless of whether the baseline is fixed or not, the changing to the drivers of MCSs will be similar moving into the future. That being that extreme cold will come primarily from advection or mixing, and not from direct surface heat fluxes. Using a fixed baseline, the authors also provide maps of where MCSs will first begin to disappear from the Med.

The study is well written, concise, and provides very interesting results. The results are rather dense throughout, making it a bit difficult to keep everything straight in ones mind, but that is difficult to avoid for a study of this nature. A lot of information is provided, and many interested readers will be able to extract a lot of relevant information from this study. The authors may want to consider putting their results up on a public repository somewhere so that the data may be downloaded and used for future studies y other teams.

I have no substantive comments and therefore recommend this article for publication more-or-less as is.

We would like to thank the Reviewer for providing their feedback and suggestions that will greatly improve the work. We acknowledge that the presentation of the information is rather condensed. In the revised version of the manuscript, we will aim at presenting our results in a more gradual and structured manner by using shorter and more clearly separated paragraphs to improve readability and facilitate the reader's understanding.

Title

- Why 'On the drivers of...'? Why not just start with 'The drivers of...'?

Response:

We thank the Reviewer for this suggestion. We chose the formulation “On the drivers of...” as it is commonly used in scientific literature to indicate an investigation or discussion of a specific topic, rather than a definitive characterization of all possible drivers. Because of that we would prefer to maintain the original title of the work.

Abstract

- Very interesting. Very succinct.

Response: Thank you very much for the feedback

1. Introduction

- In 60: 'MSC' → 'MCS'

Response: In the updated version of the manuscript all these typos will be corrected.

2. Methods

- It's an interesting idea to analyse MLT rather than SST.

– Though as one may see in the model vs satellite results, this likely has a large impact on the comparability of these two data sources. The authors acknowledge this but don't provide a solution. Ultimately though I don't think this is an issue as the analysis of MLT is a good idea. Especially for a mixed layer heat budget analysis focussed study.

- Also interesting to use the GWLs as the reference for the shifting baseline.

Response:

We would like to thank the Reviewer for providing their feedback. In the revised version of the manuscript, we will further discuss how identifying MCSs by using SST and MLT affects the statistics of the extreme events. Here, the choice of MLD is motivated by our aim to investigate the thermal processes responsible for the development of MCS, which occur within the mixed layer. This will be clearly explained in the updated version of the manuscript.

3. Results and Discussion

- In 214: "A similar..." I don't think the interpolation of satellite data is causing the mismatch. Rather the fact that MLT and SST are being compared.

- In 351: "To our knowledge..." I agree.

- In 434: "In caution" → "with caution"

Response:

We would like to thank the Reviewer for their feedback. Indeed, the differences in the identified MCS characteristics arise from the fact that SST and MLT may capture different properties of extreme temperature events. In addition, the differences between the two datasets based on which MCS were identified, such as their spatial and temporal resolution, as well as the processing methods, can influence their detected characteristics. From this point of view, previous studies (e.g., Pilo et al., 2019) on marine heatwaves have shown that differences in the resolution of the temperature datasets can lead to significant differences in the estimated event properties. This will be clearly stated and discussed in the updated version of the manuscript.

Reference: Pilo, G. S., Holbrook, N. J., Kiss, A. E., & Hogg, A. M. (2019). Sensitivity of marine heatwave metrics to ocean model resolution. Geophysical Research Letters, 46(24), 14604-14612.

4. Conclusion

- 573: "although spatial consistency with the observed MCS count and duration is weak" Likely because the authors are comparing SST with MLT.

Response:

We agree with the Reviewer's comment. This will be incorporated in the updated version of the manuscript.

Appendix

The last page appears to be blank.

Response:

We apologise for this issue. In the updated version of the manuscript this will be corrected.

Table 1-2

No comments.

Figure 1

A diverging colour palette isn't really appropriate for linearly increasing set of values (i.e. 0 to 30). Though the current palette is easy to read. As the authors prefer.

Response:

Thank you for your feedback. Several colour palettes were evaluated to identify the most suitable representation of the spatial patterns of MCS properties. Although the use of a diverging colour palette may appear counterintuitive, it was selected as it provides the clearest visualization of the spatial variability and contrasts within the results. We will retain this colorbar for this Figure in the updated version of the manuscript.

Figure 3

It's interesting that the count of MCSs between datasets over seasons are so different, while the intensities are so similar.

Response:

We would like to thank the Reviewer for this comment. The larger differences in MCS counts compared to intensities may be related to the threshold-based nature of marine temperature extreme detection. Since the identification of MCS events depends on both α threshold exceedance and duration criteria, small differences in the underlying temperature fields, variability and dataset characteristics can influence whether an event is detected, thereby affecting the total number of events. In contrast, the comparable intensities suggest that, once MCS are identified, the two (SST-based and MLT-based) datasets capture similar magnitudes of cold anomalies relative to their respective climatological conditions. This can happen, for example during sufficiently developed cooling events, where vertical mixing can lead to both the SST and MLT to capture comparable cooling magnitudes. This, in turn, may explain the similar MCS intensities despite differences in the event occurrence. This point will be commented on in the discussion section of the updated version of the manuscript.

Figure 4

It's interesting how clear the patterns are.

Figure 5

I recommend changing the colour palette for the first set of panels. Use something that doesn't have white as one of the values so it is more obvious which regions have no MCSs.

Response:

Thank you for your suggestion. Indeed the choice of this colorbar is misleading. This will be changed with a more appropriate in the updated version of the manuscript.

Figure 6 & 8

I'm not really sure I understand what these figures are showing. So red means that the future will have a greater percent of the MCS affected by forcing, advection, or mixing? How can everything be red? If this is showing percentage, shouldn't there be an equal amount of blue somewhere?

Response:

We would like to thank the Reviewer for their feedback. The apparent dominance of red across most panels is primarily due to very small values close to zero, resulting from a numerical artifact introduced during the calculation of the relative contribution of each term. These near-zero values were assigned to the red range of the colour scale, leading to a misleading visual representation. This figure will be removed in the updated version of the manuscript and will be replaced by a figure showing the basin-mean percentage of MCS driven by Forcing, Advection and Mixing throughout the 21st century. The new figure will provide a clearer representation to the reader of how the different types of events change with time and higher global warming levels.

Figure S1-11

No comments

Table S1-S7

No comments.