Reply to Reviewer 1:

We would like to thank the reviewer for their careful reading and suggestions. Please, find below a point-by-point response to all comments. For ease of reference, the reviewer's comments are presented in blue font, while the authors' responses are presented in black font.

In general, I think the study is interesting and the analysis robust. I have only two major concerns, one related to the data set used and the other more related to the motivations and implications of this work for the communities who might be interested (in particular Marine Protected Areas and aquaculture sector).

We thank the reviewer for pointing out these two aspects. We believe addressing them will add value to our manuscript. Our specific responses are provided following the reviewer's comments below.

Motivation and Innovative aspects

Which are the main innovative aspects of this work with respect to the Marin et al. (2021) which focused on the coastal analysis and used an ensemble of different SST products? In their case motivations of the work were to provide an informative framework for coastal management since they focus on the analysis of coastal MHWs. In the present work the analysis has been extended to the whole Mediterranean. Apart from the scientific interest, what are the possible implications of this analysis for marine biodiversity and ecosystem functioning across various time scales and for marine economic activities at the regional scale? It would be nice if the authors could provide more clear motivations for this study at regional level (all the Mediterranean versus the coastal region) and the implications that their conclusions might have on adaptation measures at relevant time scales.

Thank you for this valuable feedback. Our primary motivation lies in advancing scientific understanding of mean and extreme warming conditions and their drivers across the entire Mediterranean basin. In this context, expanding the analysis of Marin et al. (2021) beyond coastal locations provides a more holistic understanding of the basin. However, we recognize the need to emphasize broader motivations in the manuscript, especially concerning potential implications for marine biodiversity and ecosystem functioning.

Before applying the method of Marin et al. (2021) for attributing MHW trends, our study begins with an analysis of SST variability and extremes (99th percentile) across the Mediterranean Sea. This part aims to provide essential context on how long-term changes in extremes and variability are distributed spatially throughout the basin. This part sets the stage for the subsequent MHW analysis but also highlights areas of the basin where extreme warming is particularly pronounced and therefore might be disproportionately impacted.

For example, we find that the Adriatic, Aegean and northern Levantine Seas show the highest trends of both SST and its 99th percentile, suggesting higher vulnerability in terms of both accumulated warming and extreme SST occurrences. Such evidence is potentially useful for informing regional management strategies.

The Mediterranean Sea is a biodiversity hotspot and one of the most sensitive marine regions to climate change. By including the open sea, we account for areas that support key ecological processes which can be disrupted by MHWs. For example, pelagic species, critical to marine food webs, may be affected by MHWs, with potential repercussions for the fishery industry. A climate risk assessment by Hidalgo et al. (2022) finds the highest risks associated with impacts of ocean warming on fisheries resources (e.g., catch composition, distribution changes), highlighting the southeastern basin as the most impacted for both pelagic and demersal fisheries. Importantly, they find geographic differences in terms of drivers and impacts and recommend regionally tailored adaptation strategies.

Moreover, MHWs pose significant risks to aquaculture, which is a rapidly expanding industry in the Mediterranean Sea. Apart from fish mortality, MHWs affect aquaculture by facilitating the proliferation of pathogens and disease outbreaks, which can lead to unmarketable fish and substantial financial losses (Cascarano et al., 2021). Offshore aquaculture is increasingly being considered as an alternative to mitigate the effects of coastal warming, as it may help alleviate the impacts of extreme water temperatures (Mengual et al., 2021). In this context, a better understanding of MHWs is essential across both coastal and offshore areas.

Likewise, Marine Protected Areas (MPAs), which host vulnerable marine species, such as marine mammals and turtles (Chatzimentor et al., 2023), could benefit from a broader understanding of MHWs across the basin. Given the growing need for climate-based conservation strategies to protect marine life, it is important to enhance our understanding of extreme warming conditions at regional scale. Such insights could inform protective measures such as identifying spatial refugia and establishing new MPAs, strengthening the resilience of Mediterranean marine life to climate change (e.g., Zentner et al., 2023; Bates et al., 2019).

Considering the above, we will enrich the introduction of the revised manuscript making our motivations more explicit and addressing the ecological and socio-economic relevance of the study. Possible implications on marine ecosystems and marine economic activities will be included providing references.

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Cascarano, M. C., Stavrakidis-Zachou, O., Mladineo, I., Thompson, K. D., Papandroulakis, N., and Katharios, P.: Mediterranean aquaculture in a changing climate: Temperature effects on pathogens and diseases of three farmed fish species, https://doi.org/10.3390/pathogens10091205, 1 September 2021.Chatzimentor, A., Doxa, A., Katsanevakis, S., & Mazaris, A. D. (2023). Are Mediterranean marine threatened species at high risk by climate change? Global Change Biology, 29(7), 1809–1821. https://doi.org/10.1111/gcb.16577

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Hidalgo, M., El-Haweet, A. E., Tsikliras, A. C., Tirasin, E. M., Fortibuoni, T., Ronchi, F., Lauria, V., Ben Abdallah, O., Arneri, E., Ceriola, L., Milone, N., Lelli, S., Hernández, P., Bernal, M., and Vasconcellos, M.: Risks and adaptation options for the Mediterranean fisheries in the face of multiple climate change drivers and impacts, ICES J. Mar. Sci., 79, 2473–2488, https://doi.org/10.1093/icesjms/fsac185, 2022.Mengual, I. L., Sanchez-Jerez, P., and Ballester-Berman, J. D.: Offshore aquaculture as climate change adaptation in coastal areas: sea surface temperature trends in the Western Mediterranean Sea, Aquac. Environ. Interact., 13, 515–526, https://doi.org/10.3354/AEI00420, 2021.

Mengual, I. L., Sanchez-Jerez, P., and Ballester-Berman, J. D.: Offshore aquaculture as climate change adaptation in coastal areas: sea surface temperature trends in the Western Mediterranean Sea, Aquac. Environ. Interact., 13, 515–526, https://doi.org/10.3354/AEI00420, 2021.

Zentner, Y., Rovira, G., Margarit, N., Ortega, J., Casals, D., Medrano, A., Pagès-Escolà, M., Aspillaga, E., Capdevila, P., Figuerola-Ferrando, L., Riera, J. L., Hereu, B., Garrabou, J., and Linares, C.: Marine protected areas in a changing ocean: Adaptive management can mitigate the synergistic effects of local and climate change impacts, Biol. Conserv., 282, https://doi.org/10.1016/j.biocon.2023.110048, 2023.

Methodology

Marin et al. 2021 found important differences between the SST products mainly for the MHW mean intensity, which was well correlated to SST variability, suggesting sensitivity of this metric to the specific SST data set. Indeed, one of their conclusion is that an ensemble approach should be adopted to minimize the impact of the choice of SST product on MHW metrics. Given that, according to your results, the interannual variability is the dominant driver only of the MHW mean intensity, how robust is your result since you use only one SST product which is also re-gridded from the original 0.05° resolution to a much coarser one? Can you comment on this?

Even if it is possible to find all the details of the SST product used here in the documentation that the authors refer to in Table 1, I think it would be useful for any reader to have a short summary of the main characteristics of the product given the possible sensitivity of the results to the specificities of the SST satellite product.

Thank you for your comment. In this study we chose to use the satellite–derived Mediterranean SST product from Copernicus Marine which has been widely used and validated. This reprocessed product is a gap-free, gridded product derived from a combination of satellite observations and in situ data, with high temporal and spatial resolution (0.05° daily data). The product is extensively validated against drifter buoy measurements as outlined in its Quality Information Document (Pisano et al., 2023), confirming its suitability for MHW studies.

The dataset was regridded to a coarser resolution to ensure efficient processing and analysis of results across the basin, given the large data volume and the multiple experiments conducted. Importantly, this step did not compromise the accuracy of the results or the ability to capture the spatial patterns of interest, as the key features and variability relevant to the objectives of our analysis are effectively represented.

We note that our results for coastal locations are highly consistent with those of Marin et al. (2021) for all the commonly used MHW metrics, despite the difference in products and the study period as well. In addition, the sensitivity experiments we performed changing the climatological baselines for MHW detection further support the key role of interannual variability for mean intensity trends. The differentiation of mean intensity from the other metrics is consistently observed across the three sensitivity experiments suggesting that a less predictable bahavior should be expected for this metric, in agreement with the findings of Marin et al. 2021 based on four SST products. This consistency with their study despite the different datasets gives us further confidence in the robustness of the current findings. Nonetheless, we believe it is important to acknowledge in the revised manuscript the benefits of employing an ensemble approach. The Methods section will also be enhanced with additional characteristics of the SST product, following your suggestion.

Minor comments:

Line 99.

What do you mean exactly by "*MHWs derived from both datasets are therefore relative to the initial state of the study period (1982)*"?

Thank you for your comment. Long-term SST trends were removed from the SST time series before calculating the daily SST climatology. As noted in L.97, the climatology constructed based on the detrended SST dataset is used for the detection of MHWs in both the non-detrended and detrended datasets, following the approach of Marin et al. (2021). This climatology does not include contributions from the long-term SST trend to the SST variance, it therefore represents the climatological state at the start of the study period (1982). In this sense, MHWs are identified with respect to these climatological conditions, in both datasets. We will add a brief clarification in the revised manuscript based on this explanation.

Lines 156-157

Our findings therefore indicate that, on top of the underlying mean warming, a large part of the western and central Mediterranean basin mainly experiences increased variability…

Fig.1c is not showing this. Most of the western Med shows decreased variability and in most of the central Med the trend of STD is not significant. I suggest that all the conclusions related to this statement should be revised.

Thank you very much for noting this. Indeed, rather than a "large part" of the western and central basin, there are only distinct areas that show statistically significant increase in SST variability. We will revise this sentence as follows:

"Our findings therefore indicate that, on top of the underlying mean warming, few distinct areas, primarily in the western basin, experience increased SST variability, while most of the eastern basin and the region south of the Balearic Islands show reduced variability."

We note that there are no conclusions based on the content of this (non-revised) sentence later in the manuscript, so no further revisions to conclusions are needed.

Fig.2 shows the temporal evolution of all the different MHWs metrics, but not the linear trend (see Legend).

Thank you for noting this. We will remove "*and linear trends*" from the legend, as these are presented in the Table instead.

The legend of Fig.2 and Table 2 report twice the definition of the geographical areas.

Thank you for your comment. To improve clarity, we will remove the duplicate and show the geographical areas in the first panel of Fig. 1, making it easier for readers to refer to.

In general, the quality of the figures could be improved. In particular, the use of the same color bar but for different ranges of values in Fig.3 does not help an immediate interpretation.

Thank you for noting this issue. We agree that varying ranges can make interpretation less immediate. However, all metrics except for mean intensity have comparable ranges of TAR values. For this reason, using a different range of values only for mean intensity allows for a better visualization of the spatial distribution of TAR across the basin. This approach was a compromise between consistency (using the same color palette among MHW metrics for visualising TAR), and interpretability. For the latter, the legend alerts readers to this color bar difference for mean intensity.