

Dear Editor,

We thank you and the two referees for the careful and constructive evaluation of our manuscript. We have substantially revised the paper in response to all comments. The revised version has been deeply restructured, the methodological framing has been clarified, and the attribution claims have been reformulated more carefully and consistently throughout the manuscript.

The main revision concerns the conceptual framing of the analogue methodology. In the original submission, the distinction between our SST-based analogue framework and the more classical circulation-based analogue attribution approach was not sufficiently explicit. In the revised manuscript, this distinction is now introduced clearly already in the title, abstract, and introduction. We now emphasize that the study first identifies analogues of the observed June 2025 SST anomaly pattern and only subsequently analyses the associated atmospheric and surface conditions. The manuscript therefore focuses on comparing similar SST anomaly patterns across different climate backgrounds rather than reconstructing identical atmospheric states.

Following the referees' recommendations, we also substantially revised the attribution framing. The manuscript now explicitly states that the method provides an observational, conditional, and process-oriented line of attribution evidence, rather than a complete probabilistic attribution assessment. We clarify throughout the text that the analogue framework cannot fully separate externally forced trends from internal variability and does not explicitly resolve ocean dynamical processes such as advection, vertical mixing, mixed-layer variability, or subsurface heat storage. Several formulations that were previously too strong regarding causality or likelihood have therefore been removed or reformulated.

The manuscript structure has also been significantly improved. The introduction has been shortened and refocused on Mediterranean marine heatwaves, the June 2025 event, and the role of SST analogue approaches within the broader attribution literature. Data and methods are now presented together in a unified section. The analogue selection procedure, anomaly definitions, bootstrap significance testing, climate indices, and analogue quality metrics are now described explicitly and more transparently.

The Results section has been reorganized to remain strictly figure-based and descriptive. Interpretive statements and broader physical implications have been moved to the Discussion section. We also revised the event characterization and replaced Figure 1 with a new figure showing both the temporal evolution and the spatial structure of the marine heatwave intensity across the Mediterranean basin. This clarifies the western Mediterranean focus adopted in the subsequent analysis.

The discussion of radiative and turbulent fluxes has also been made more cautious and more closely aligned with the figures. We now explicitly state that the clearest and most spatially coherent signal concerns shortwave radiation, whereas longwave radiation, turbulent fluxes, and wind speed exhibit weaker and more heterogeneous present-minus-past differences. The revised manuscript avoids overinterpreting these fields and clearly distinguishes displayed results from broader physical interpretation. In response to the referees' requests for a clearer quantification and a sharper statement of what the SST-

analogue method adds beyond formal model-based attribution, we have added two new paragraphs to the Discussion: a first-order quantification of the conditional present-minus-past shifts in SST, T2m, and SSR over significant grid points, and a dedicated paragraph explaining that, unlike CMIP-class risk-ratio attribution, our framework returns spatially resolved, multi-variable composite differences for one specific event and so isolates which surface energy budget terms shift most coherently between past and present analogues.

In addition, we revised the discussion of large-scale climate variability modes. ENSO, PDO, AMO, NAO, EA, and SCAND are now presented as descriptive background information associated with the analogue populations rather than as demonstrated causal drivers of the 2025 event.

Finally, the conclusions have been rewritten substantially. Unsupported claims regarding pre-industrial likelihood and formal attribution have been removed. The revised conclusions now state that the SST analogue framework provides an event-specific observational line of evidence consistent with thermodynamic amplification of the June 2025 Mediterranean marine heatwave in a warmer climate background, while clearly acknowledging the methodological limitations of the analogue approach.

We believe that the revised manuscript is now substantially clearer, more rigorous in its interpretation, and better positioned within the broader literature on marine heatwave attribution and analogue-based diagnostics.

A detailed point-by-point response to all referee comments is provided below.

Sincerely,

The authors

Response to Referee #1

We thank the referee for the careful reading of the manuscript and for the constructive and encouraging comments. We appreciate the recognition that the study proposes a perspective that differs from the standard use of analogue-based attribution approaches. The suggestions provided by the referee helped us substantially clarify the methodological framing of the manuscript and improve the presentation and interpretation of the results.

In the revised manuscript, we now make explicit from the title, abstract, and introduction that the study does not follow the classical circulation-first analogue attribution framework. Instead, we first identify analogues of the observed SST anomaly pattern associated with the June 2025 Mediterranean marine heatwave and only afterwards analyse the atmospheric and thermodynamic context associated with those analogue dates. We also revised the attribution framing throughout the manuscript. The revised version now explicitly states that the method provides an observational and conditional line of evidence consistent with

thermodynamic amplification in a warmer climate background, while not constituting a complete formal probabilistic attribution assessment.

Below we provide a detailed point-by-point response to all comments.

“Summary: The manuscript presents a novel application of the analogue method to attribute a Mediterranean heat wave to anthropogenic climate change. Although the application of the analog method for attribution is not new, this study adopts a different perspective: instead of searching for analogs of the atmospheric circulation and then comparing the observed extreme with those analog dates, this study searches for analogs dates of the observed extremes and then compares the atmospheric circulation of those dates with that observed at the dates of the extreme. The conclusion reached for this particular Mediterranean heat wave is that the atmospheric dynamics in the past, while similar to that observed in the extreme, were linked to higher radiative and thermodynamic forcings.”

We thank the referee for recognizing the different methodological perspective adopted in the manuscript. In the revised manuscript, we now emphasize this distinction explicitly in the title, abstract, and introduction. We clarify that the analogue search is performed in SST anomaly space rather than in circulation space, and that the subsequent analysis compares the atmospheric and thermodynamic context associated with these SST analogue events across two different climate backgrounds.

“Recommendation: I found the study interesting and, as I wrote above, considering this novel perspective that complements the standard application of the analog method for attribution. I have a recommendation that the authors may want to consider in a revised version”

We thank the referee for the positive assessment and constructive recommendations.

Main points

“1) The title and the abstract do not suggest that the perspective adopted in this study is different from other applications of the analog method. So the authors could better highlight this novel aspect. When reading the title, I first thought that this would be 'just another attribution study'. However, it is not, but this becomes clear when reading the complete manuscript. So I would recommend amending the title and the abstract.”

We fully agree. The title and abstract have been rewritten to make the methodological perspective explicit from the beginning. The revised title now refers directly to SST analogues, and the abstract clearly states that the analogue search is performed on SST anomaly patterns rather than on atmospheric circulation. The introduction has also been revised accordingly.

“2) In the conclusions section, the authors fall into their own trap and write some sentences as if the conclusions came from a standard analog-attribution study. For instance, in line 389 they write 'This approach yields a physically transparent storyline: given the same atmospheric/oceanic setup that lead to the 2025 heatwave, a mid-20th-century climate would have produced a far less severe event'. However, this is not what the study has done. It has not explored the outcome of the same (or similar) atmospheric/oceanic set up - it has explored the differences in the predictors of analogous heat waves”

We agree with the referee. The original wording was too strong and implied a counterfactual interpretation not supported by the method. This sentence and related formulations have been removed. In the revised manuscript, we now state more carefully that the analogue framework compares atmospheric and thermodynamic conditions associated with similar SST anomaly patterns across different climate backgrounds. The conclusions now frame the results as evidence consistent with thermodynamic amplification in a warmer climate rather than as a causal reconstruction of identical dynamical states.

“3) This different attribution scope, though interesting, makes it more difficult to quantify the impact of climate change. In the traditional approach, the difference between, say, the mean of past analogs and the observed extreme would be the climate change signal. But how can one quantify, with the approach presented in this manuscript, the contribution of climate change? Actually, the authors do not provide a number, perhaps because it is indeed more difficult to obtain. This should be discussed.”

We thank the referee for this important point. In the revised manuscript, we now discuss this limitation explicitly in both the Discussion and Conclusions sections. The framework used here does not provide a single scalar estimate of the climate change contribution comparable to probabilistic attribution metrics or circulation-first analogue approaches. Instead, the method provides conditional diagnostics of how the thermodynamic and radiative environments associated with similar SST anomaly patterns differ between earlier and more recent periods. To make this more concrete, we have also added a first-order quantification of the conditional shift in the revised Discussion. Over the grid points where the present-minus-past difference is significant at the 95% level after bootstrap and FDR correction, the SST shift typically reaches +1 to +1.5 °C across broad sectors of the western Mediterranean and parts of the Adriatic, T2m shifts over surrounding land are locally in the +1.5 to +2.5 °C range, and SSR differences are of order a few W m^{-2} over much of the western and central basin. We present these as conditional ranges rather than as a single point estimate of the human contribution, and we explicitly state that internal variability associated with the low-frequency modes sampled by the analogue populations also contributes to these magnitudes. We also strengthened the discussion of internal variability and the inability of the analogue framework to fully separate externally forced trends from low-frequency variability.

Minor points

“4) 'we compared historical sea surface temperature (SST) patterns from ERA5 reanalysis (1950–2024) to those observed during the event.' The SST from the ERA5 reanalysis come from two different sources, as the manuscript clearly states, depending on the period. However, in neither of these two periods are the SSTs a 'reanalysis' product in the classical sense. The OSTIA SSTs are indeed the result of a data assimilation methodology, but the 'model' is very simple, just persistence of the previous time step. A reader may think that SSTs are also the result of data assimilation of observations and a proper ocean model.”

We thank the referee for this important clarification. The revised manuscript now explicitly states that ERA5 SST relies on observationally constrained SST analyses rather than on a fully coupled ocean reanalysis. We now distinguish more carefully between the atmospheric reanalysis framework and the SST products used within ERA5.

“5) Figure 1. 'Time series of daily sea surface temperature (SST) anomalies averaged (standard deviation shaded in grey)' I cannot see the shaded area in the downloaded pdf file. Perhaps the rendering of the figure is not totally correct”

Figure 1 has been completely redesigned in the revised manuscript. The new version now shows the temporal evolution of western Mediterranean SST together with MHW categories and the spatial structure of the event intensity across the Mediterranean basin. The rendering issue is therefore no longer present.

“6) Section 5 consists of just one big paragraph (!). I would recommend splitting the paragraph, perhaps by the variables being described, to help the reader.”

We agree. The former single-paragraph section has been completely reorganized into Sections 4.1–4.5, corresponding respectively to SST analogue composites, near-surface air temperature and pressure, radiative fluxes, turbulent heat fluxes and wind speed, and climate variability indices and analogue quality. This substantially improves readability and clarity.

“7) 'STR (q–t) presents positive Present–Past differences, implying reduced net longwave loss in the present climate, consistent with a warmer, moister atmosphere returning more longwave radiation to the surface (Trenberth et al., 2015; Vautard et al., 2023)' I think this paragraph and the corresponding figure warrant a more detailed discussion or description. In principle, attributing it to climate change would entail stronger long-wave forcing from greenhouse gases. Feedbacks increase specific humidity, thereby amplifying the greenhouse effect. But in theory, another scenario is possible: solar radiation increases, warming the ocean surface and increasing specific humidity. In this scenario, anthropogenic climate change would not be ultimately responsible, or only indirectly through reduced cloudiness. So there are subtle questions to discuss based on this figure. A clean attribution would find that the same MHW is linked to a similar or smaller solar radiation and to increased longwave radiation. I am aware that this reduces the number of possible analogs, but again, this seems to me to be a complication of this novel attribution approach.”

We thank the referee for this nuanced and important comment. In the revised manuscript, we substantially revised the discussion of the radiative fluxes. We now state explicitly that the STR signal is spatially heterogeneous and cannot be interpreted as a simple basin-wide increase in longwave forcing. We also clarify that several mechanisms may contribute to the observed radiation patterns, including changes in cloudiness, humidity, thermodynamic background conditions, and long-term drying trends. We avoid attributing the signal to a single process and explicitly acknowledge that cloud cover and humidity were not directly analysed in the present framework. The revised discussion therefore presents the radiative fields as part of a broader surface energy budget context rather than as isolated causal diagnostics.

We thank the referee for the detailed, careful, and constructive review of the manuscript. We agree that the original version did not sufficiently distinguish between figure-supported results, physical interpretation, and the scope of the attribution claims. Following the referee's recommendations, we substantially revised the manuscript structure, clarified the methodological framing, moderated several statements regarding attribution, and strengthened the discussion of limitations.

The revised manuscript now explicitly states that the analogue framework provides an observational, conditional, and process-oriented line of evidence rather than a complete formal probabilistic attribution assessment. We now clearly distinguish the present SST-first analogue framework from more classical circulation-first analogue attribution approaches. The revised manuscript also explicitly acknowledges that the framework cannot fully separate externally forced trends from internal variability and does not explicitly resolve ocean dynamical processes such as advection, vertical mixing, mixed-layer variability, and subsurface heat content.

The manuscript structure has also been substantially reorganized. The introduction has been shortened and refocused on the June 2025 Mediterranean marine heatwave and on the role of SST analogue approaches within the broader attribution literature. Data and methods are now presented together in a unified section. The Results section has been reorganized into dedicated subsections and restricted more closely to figure-supported statements, while broader interpretation and literature comparisons have been transferred to the Discussion section.

Below we provide a detailed point-by-point response to all comments.

“The authors present an analysis of the 2025 Mediterranean marine heatwave (MHW). Using an analogue-based approach, they examine SST anomalies and synoptic conditions in a past (1950-2024) and a present (1987-2024) period, in order to assess the atmospheric conditions, conducive to the development of similar events in these two periods, in comparison to the conditions associated with the 2025 event. While the results are broadly consistent with the growing body of literature documenting the intensification of Mediterranean MHWs and their atmospheric drivers, the current manuscript does not yet provide sufficiently robust evidence to support its main attribution-related claims.”

We thank the referee for this important assessment. In the revised manuscript, we substantially revised the attribution framing throughout the paper. The manuscript now explicitly states that the method provides an observational and conditional line of evidence consistent with thermodynamic amplification in a warmer climate background, rather than a complete formal attribution assessment. We also revised the conclusions and removed formulations implying stronger causal attribution than supported by the framework.

“A key concern is the methodological interpretation. Although the analogue method is a useful tool for identifying historical precursors and exploring variability of atmospheric drivers, it cannot on its own provide formal attribution of events to anthropogenic climate change. At several points in the manuscript, the results derived from the analogue framework appear to be treated as a direct proxy for the influence of anthropogenic climate change on the occurrence of the event. In addition, many of the results rely primarily on qualitative comparisons and visual inspection rather than on a clearly defined quantitative

framework, which leaves parts of the analysis more descriptive than substantiated. Also, the study focuses on the atmospheric drivers of the 2025 event, with the role of oceanic processes being largely neglected in the analysis and only briefly acknowledged in the limitations of the study.”

We agree with the referee that the original wording overstated the attribution scope of the analogue framework. In the revised manuscript, we now explicitly clarify that the framework does not constitute a complete formal attribution assessment and cannot fully separate externally forced trends from internal variability. We also strengthened the quantitative description of the methodology, including the analogue selection procedure, Euclidean distance metric, bootstrap significance testing, and analogue quality diagnostics. In addition, the discussion of limitations has been substantially expanded, especially regarding omitted ocean dynamical processes such as advection, mixed-layer variability, vertical mixing, and subsurface heat storage.

“To strengthen the manuscript, I suggest reconsidering the framing of the conclusions. In particular, the authors may wish to avoid drawing definitive inferences regarding the causality or likelihood of the event under climate change. Such questions are typically addressed through formal attribution studies using climate model ensembles, and the influence of anthropogenic climate change on the increasing likelihood and intensity of Mediterranean MHWs is already well established in the literature. As a result, attempting to infer this within the current framework, without a formal attribution approach, does not substantially advance existing understanding of the topic. Instead, the study could focus more on the specific insights that the analogue approach may provide in comparison to existing methods. Clarifying whether and in what ways this approach may offer additional physical understanding or diagnostic value specifically for the 2025 event, beyond established analyses would perhaps help better define the contribution of the study. At present, however, this added value (if any) is not yet clear.”

We thank the referee for this constructive suggestion and revised the manuscript accordingly. The conclusions have been substantially rewritten and no longer contain strong probabilistic or counterfactual attribution claims. Instead, the revised manuscript now emphasizes the specific contribution of the SST analogue framework, namely providing an event-specific observational and process-oriented comparison of similar SST anomaly patterns across different climate backgrounds. We have added a dedicated paragraph in the Discussion clarifying what the SST analogue framework adds beyond formal probabilistic attribution. Model-ensemble attribution typically delivers a scalar return-period or risk-ratio change for a regional SST or MHW index, whereas, by construction, our framework holds the SST anomaly pattern approximately constant and returns spatially resolved, multi-variable composite differences for SST, T2m, MSL, SSR, STR, SLHF, SSHF, and WSPD from observation-constrained reanalysis fields. This makes it possible to identify, for the specific June 2025 event, which surface energy budget terms shift most coherently between past and present analogues (here SST, T2m, SSR) and which remain weak and spatially heterogeneous (here MSL, STR, SLHF, SSHF, WSPD), a variable-by-variable, grid-point-resolved diagnostic that CMIP-class risk-ratio attribution does not provide. We therefore position the method explicitly as complementary to formal model-based attribution studies rather than as an alternative to them.

“Overall, a major revision that addresses the detailed comments below and refocuses the manuscript on the methodological and physical insights provided by the analogue analysis (rather than on causal attribution) would substantially improve the clarity and impact of the study. In addition, the manuscript would benefit from improvements in structure and clarity. For instance, the introduction remains quite general and is not sufficiently aligned with the specific objectives of the study, while the Results section at times blends results with discussion. A clearer organization and a more cohesive, logically structured narrative would strengthen the presentation of the work.”

We agree and substantially reorganized the manuscript. The introduction has been shortened and refocused on Mediterranean marine heatwaves, the June 2025 event, and the methodological role of SST analogue approaches. The Results section has been reorganized into separate subsections and restricted more closely to figure-supported results. Broader interpretation and comparisons with previous literature have been transferred to the Discussion section.

Abstract

“Line 14: ‘...raising questions about the influence of human-induced climate change.’ This is not a novel question as the relationship between climate change and the increasing occurrence and intensity of Mediterranean MHWs is already well documented in the literature.”

We agree and revised this sentence. The revised abstract no longer presents the climate change influence on Mediterranean MHWs as a novel question in itself. Instead, we now position the study within the already established literature and clarify that the contribution of the manuscript is the event-specific SST analogue framework and its process-oriented diagnostic perspective.

“Line 19: It is unclear how this result provides new insights compared to existing studies that have addressed similar questions using other methods.”

We revised the abstract to clarify the specific contribution of the study. The revised version now explicitly states that the SST analogue framework compares similar SST anomaly patterns across different climate backgrounds and diagnoses how the associated thermodynamic and atmospheric conditions differ between earlier and more recent periods.

“Line 25: ‘...method for assessing extreme events, also including marine heatwaves, in a warming Mediterranean context’”

We revised this wording for clarity and precision.

Introduction

“Line 29: A MHW is not an extreme weather event, it is an extreme marine event.”

We agree and corrected this terminology throughout the manuscript. The revised manuscript now consistently refers to marine heatwaves as extreme marine events rather than extreme weather events.

“Lines 40-45: This literature background on global MHW impacts is already known and less relevant to the 2025 Mediterranean event. The paragraph could be condensed to focus on Mediterranean MHW impacts and the specific insights the study seeks to gain using the analogue method.”

We agree and substantially shortened this section. The introduction is now more tightly focused on Mediterranean marine heatwaves, the June 2025 event, and the specific role of the SST analogue framework.

“Line 51: ...The Mediterranean Sea...”

This has been corrected.

“Lines 51-53: How is the series of record-breaking marine heatwaves different from the immediately previous sentence on frequency, intensity and duration of MHWs? These two sentences convey the same information.”

We agree and merged these statements into a more concise description of the observed intensification of Mediterranean marine heatwaves.

“Lines 56-60: This is not a new regime. MHWs are already known to be becoming more frequent and intense as a result of the mean warming. Especially in the Mediterranean Sea. It is unclear what is novel here. The sentence is also too long: terms like 'conditioning synoptic circulation' need clarification. What exactly is meant by these phrases?”

We revised this paragraph substantially. The revised manuscript no longer refers to a “new regime” and now frames the discussion more carefully in terms of increased co-occurrence between marine and atmospheric heat extremes under long-term warming conditions. We also clarified the circulation-related wording.

“Lines 61-64: These two sentences are redundant. The question raised here and the effect of anthropogenic climate change on individual extreme events is already well established globally and regionally. It would be more useful to focus on the analogue method itself and clarify how it complements or differs from previous studies addressing similar questions in the Mediterranean Sea.”

We agree and revised this section accordingly. The introduction now focuses more directly on the methodological perspective and on the SST analogue framework itself rather than restating the broader attribution context.

“Line 75: The role of atmospheric dynamics in Mediterranean MHWs has already been highlighted multiple times in previous observational and modeling studies. It would be helpful to clarify what (or if) the analogue method adds beyond these earlier investigations of atmospheric forcing, for the specific 2025 event.”

We clarified this point in both the Introduction and Discussion sections. The revised manuscript now states more explicitly that the analogue framework provides an event-specific observational comparison of similar SST anomaly patterns across different climate backgrounds, thereby complementing existing dynamical and attribution studies rather than replacing them.

“Lines 86-90: This reads more like a Methods section than an Introduction. Consider moving the detailed description of the analogue approach to Methods and in the Introduction focus on clearly stating the main goal of the paper.”

We agree and moved the technical description of the analogue methodology to the Methods section. The Introduction now contains only a concise conceptual presentation of the approach.

“Data: There should be a section describing the method and datasets together. Not separately.”

We agree and reorganized the manuscript accordingly. Data and methods are now presented together in a unified “Data and Methods” section to improve readability and avoid repetition.

“Line 109-110: It is unclear what is meant by ‘average’ here. Is this a spatial average over 20-30 June, a temporal average, or both? Are the daily SST anomalies calculated first and then averaged, or was the mean SST over 20-30 June computed before subtracting the climatology? Do these approaches yield similar results?”

We clarified this procedure explicitly in the revised manuscript. Daily SST anomalies are first computed for each calendar day relative to the daily climatology and are then temporally averaged over the 20–30 June period. The target event is therefore a temporally averaged SST anomaly field rather than a single-day snapshot.

“Are these the actual dates (20-30 June) of the 2025 MHW? If so, the Introduction should include a brief description of the event, rather than just listing the dates, to explain why this period was selected.”

We agree and added a dedicated event characterization section describing the evolution, timing, and spatial structure of the June 2025 Mediterranean marine heatwave. We also explain explicitly why the 20–30 June period was selected as the target analogue window.

“Line 115: This appears redundant with the previous sentence. Additionally, the term ‘distances’ is introduced for the first time here and is unclear. Please clarify its meaning by describing the method where the method section is.”

We revised this section and now define explicitly the Euclidean distance metric used for analogue selection. The revised manuscript now explains clearly how distances are computed over the SST anomaly fields and how analogue dates are ranked.

“Lines 126-132: The dataset details here are excessive; providing just the link is sufficient. The term ‘refer to’ is unclear and it should be explained why this observational dataset was chosen.”

We simplified the dataset description and clarified the role of the MED-REP-L4 dataset. The revised manuscript now states explicitly that this dataset is used only for descriptive event characterization and not within the analogue selection framework.

“Lines 133-135: Do you mean the daily Mediterranean-mean SST from the satellite dataset? If so, please clarify. It is also unclear how the timing and magnitude of the 2025 MHW can be compared using a 1991-2020 baseline when the ERA5 anomalies discussed in the study are based on 1950-2025. Can similar anomalies be expected with different climatologies? Since the satellite observations cover 1991-2020, shouldn't the 'present-climate' period be the same to allow a proper comparison? Additionally, please clarify which years are considered as 'previous years.'”

We thank the referee for this important point. To avoid ambiguity related to different climatological baselines, Figure 1 has been redesigned and now presents absolute SST values and MHW categories rather than anomaly comparisons between datasets. We also clarified explicitly the distinction between the event characterization dataset and the ERA5 anomaly framework used for the analogue analysis.

“Lines 136-137: I do not understand how OISST is being used. What is meant by 'descriptive purposes'? If Level-4 AVHRR data are already used, what is the added value of including another observational dataset? Please clarify how this dataset is applied and which reference period was used to compute anomalies.”

We clarified this section substantially. The revised manuscript now explains explicitly that the observational dataset is used only to characterize the timing, intensity, and spatial structure of the event independently from ERA5. The analogue analysis itself relies exclusively on ERA5-derived SST anomalies.

Methodology

“Line 143: maybe you meant analogue events? Also the description feels a lot like repeated from the introduction.”

We corrected the wording and reduced repetition between the Introduction and Methods sections.

“Line 144: The phrase 'dynamical situation' may be unclear. Here, it would be more precise to refer specifically to the relevant atmosphere state or circulation pattern that drives the observed SST anomalies, rather than implying the entire coupled system, since no ocean variables are included.”

We agree and revised the wording throughout the manuscript to avoid implying that the full coupled ocean-atmosphere system is represented.

“Line 148: Since this refers to an SST anomaly pattern, it should pertain only to the sea, including coastal regions, unless another aspect is intended, which should be clarified.”

We clarified this point. The analogue matching domain now explicitly refers to the Mediterranean SST anomaly field and adjacent coastal grid points represented in ERA5.

“Lines 152-155: In this description it is unclear whether the closest analogues at each grid point occur on the same days, or how analogue days are selected. Is a spatial average of the distances across grid points computed for each day to identify candidate analogue dates? Please clarify how analogue days are determined consistently.”

We revised the methodological description substantially. The revised manuscript now explains explicitly that the Euclidean distance is computed over the full SST anomaly field for each candidate day and that analogue dates are selected based on the smallest basin-wide distances.

“Lines 155-159: What is meant by ‘fix the number of analogues’? You also mention that earlier sensitivity analyses provided robust results. Please specify which analyses were performed and how they support this conclusion.”

We clarified this point in the revised manuscript. We now explicitly state that the top 1% of analogue dates are retained in each period, corresponding here to 42 analogue dates. We also clarify that this choice follows the standard Climameter framework adopted in previous sensitivity analyses.

“Lines 162-163: You have already stated that in the beginning of the paragraph. Maybe merge?”

We merged these sentences and removed the redundancy.

“Lines 167-168: what do you mean by ‘avoid introducing biases from model simulations’? ERA5 is a reanalysis product that assimilates observations and therefore inherently includes biases and errors, so the purpose of this statement is unclear.”

We agree and revised this wording. The revised manuscript no longer implies that reanalysis products are bias free. Instead, we now describe the framework as observation-constrained rather than purely model-generated.

“Lines 170-171: It is still unclear why 42 events were selected, why this number and not another? Additionally, the manuscript has already emphasized multiple times that the analysis compares different background climate conditions.”

We clarified this explicitly. The revised manuscript now states that the 42 analogue dates correspond to the top 1% of analogue matches in each subperiod and that the same number is retained in both periods to allow direct comparison between analogue composites.

“Line 178: main drivers of MHWs during the summer perhaps?”

We agree and revised the wording accordingly to specify that the discussion refers to summer Mediterranean marine heatwaves.

Results

“Lines 215-216: Before presenting the Mediterranean-averaged SST anomaly timeseries, it would be more informative to show a map of the event’s spatial pattern. This would justify focusing on the Western Mediterranean rather than the entire basin.”

We agree and redesigned Figure 1 accordingly. The revised figure now includes both the temporal evolution of western Mediterranean SST and the spatial distribution of MHW intensity across the Mediterranean basin during the peak phase of the event. This clarifies why the subsequent analysis focuses on the western Mediterranean.

“Line 217: It is unclear why the 1991-2020 climatology was chosen. According to the Methods, the ‘present climate’ period is 1987-2024, so it would be more consistent to calculate the MHW SST anomalies relative to the same period.”

To avoid ambiguity associated with different climatological baselines, the revised Figure 1 now presents absolute SST values and MHW categories rather than anomaly comparisons between datasets.

“Lines 221-223: would these results still hold if a climatology of 1987-2024 was used?”

We revised the wording to avoid statements that would depend on untested alternative climatologies. The revised text now presents the event characterization more cautiously and avoids overstating quantitative comparisons across different baseline periods.

“Lines 225-227: What is meant by ‘in the context of recent warming’? Which period does ‘recent warming’ refer to? Also, would this statement still hold if the climatology were shifted to 1987-2024?”

We clarified this wording and now refer more explicitly to the observed long-term warming trend documented in the Mediterranean literature rather than to a specific climatological baseline comparison.

“Lines 228-230: The reader does not see a map of SST anomalies for the entire basin.”

This issue has been addressed through the redesigned Figure 1, which now shows the basin-wide spatial structure of the marine heatwave intensity during the event peak phase.

“Line 233: The phrase ‘embedded in a basin-wide warming’ is misleading.”

We agree and revised this wording to describe the spatial structure of the event more precisely without implying homogeneous basin-wide conditions.

“Line 237: This belongs in the Discussion rather than the Results.”

We agree and moved these interpretive statements to the Discussion section.

“Lines 237-240: The figures label the variable as MSL, not MSLP, this should be made consistent throughout.”

We corrected the notation throughout the manuscript and now consistently use MSL.

“Line 242: We are still in the Results section, so it is premature to compare with the literature.”

We agree and transferred these comparisons with previous studies to the Discussion section.

“Line 244: Again, this is Results section, the focus should be on presenting the findings.”

We revised the Results section accordingly and restricted it more closely to figure-supported descriptions.

“Line 245: According to the caption of Figure 2.1, the data represent the average over 20-30 June, so no figure shows the specific conditions on 30 June as mentioned in the text.”

We corrected this inconsistency in the revised manuscript.

“Line 246: The analysis does not include cloud cover, only wind is shown.”

We agree and removed references to cloud cover from the Results section. The revised manuscript now refers only to variables explicitly analysed and shown in the figures.

“Line 248: If this is the case, it should be addressed in the Discussion section.”

We agree and moved these interpretive statements to the Discussion section.

“Lines 253-254: This result is not novel and has already been documented in previous Mediterranean studies. This discussion belongs in the Discussion section. While the observed 6 °C air-temperature anomaly may suggest a local atmospheric heatwave, this has not been formally demonstrated.”

We agree and revised this section accordingly. The interpretive comparison with previous studies has been moved to the Discussion section, and we now avoid implying a formally identified atmospheric heatwave where no dedicated atmospheric heatwave definition was applied.

“Line 255: Again, I did not see anywhere the cloud variable been presented.”

We removed these references from the revised manuscript.

“Line 259-261: What is the purpose of Figure 1 without a map showing the full spatial pattern of the event across the entire basin?”

This issue has been addressed through the redesigned Figure 1, which now combines the temporal evolution of western Mediterranean SST with a basin-wide map of MHW intensity during the event peak phase.

“Line 263: ...record-breaking”

We revised this wording for greater precision and moderation.

“Line 265: Did the studies you compare your results with use the same climatology to define the 2022 events? If different climatologies were used, it is unclear how these comparisons are valid.”

We agree and moved these comparisons to the Discussion section while also moderating the wording to avoid overstating quantitative comparability between studies using different baselines.

“Lines 266-267: There is no information on the spatial extent of the event or how it differs from previous events.”

We addressed this issue through the redesigned Figure 1 and by adding a more explicit description of the spatial distribution and intensity of the event across the Mediterranean basin.

“Lines 268-269: Again, comparisons with previous studies belong in the Discussion section.”

We agree and transferred these comparisons to the Discussion section.

“Line 269: which event? the 2003 or 2025? clarify.”

We clarified the wording in the revised manuscript.

“Line 270: It is unclear which figure this description refers to.”

We revised all figure references carefully throughout the manuscript to avoid ambiguity.

“Lines 273-275: This statement is expected given the mean warming of the basin. it is unclear what is novel about this argument.”

We revised the wording to avoid overstating novelty. The revised manuscript now frames these results more carefully as event-specific observational diagnostics rather than as fundamentally new evidence of Mediterranean warming.

“Line 278: ...described in Section 2..”

We corrected this cross-reference.

“Lines 281-287: This content does not present results. It corresponds to a figure caption and is not relevant to the main text.”

We removed and condensed this passage accordingly.

“Lines 289-292: Aside from the warmer background and increased MHW frequency, these results are largely expected.”

We agree and revised the wording to avoid overstating novelty. The revised manuscript now frames the results more carefully as a conditional observational comparison between analogue populations rather than as unexpected findings.

“Lines 292-294: Which figure does this refer to?”

We clarified the figure references and domain descriptions throughout the revised manuscript.

“Line 294-295: Co-variability of what? Clarify.”

We clarified this wording in the revised manuscript.

“Lines 295-297: The statement that the ‘actual event exceeds both composites’ is unclear.”

We revised this passage to specify explicitly which variables and analogue composites are being compared and in what sense the target event differs from them.

“Lines 297-301: These belong to the Discussion section again.”

We agree and moved these interpretive statements to the Discussion section.

“Line 304: Since the study does not demonstrate that the SSR patterns are actually linked to anticyclones, this should be framed as a hypothesis rather than a fact.”

We agree and revised the wording accordingly. These interpretations are now presented more cautiously as possible mechanisms rather than demonstrated causal relationships.

“Lines 308-309: Has it been demonstrated that higher absolute humidity causes the weaker and more spatially mixed SLHF patterns?”

We agree that this interpretation was too strong. The revised manuscript now presents this point more cautiously and only within the Discussion section.

“Line 309: The differences in SSHF shown in Fig. 2 are actually negative around the Mediterranean basin and near zero over the Mediterranean Sea.”

We corrected the description so that it now matches the displayed SSHF patterns more accurately.

“Lines 313-314: What is meant by ‘modest MSL differences’? What does ‘indicating similar dynamics’ refer to?”

We revised this passage substantially. The revised Results section now remains more strictly descriptive and avoids overinterpreting weak or spatially heterogeneous dynamical fields.

“Line 325: What defines an ‘anomalous circulation pattern’?”

We clarified and simplified this wording in the revised manuscript.

“Lines 327-329: Based on Fig. 2d,h,l,p,t,x,ab,af, the results show...”

We thank the referee for this close reading. We carefully revised the corresponding sections so that the textual descriptions now match the figures more precisely. We also revised the discussion of longwave radiation, latent heat fluxes, and wind speed to avoid overstating their spatial coherence or physical interpretation.

“Lines 329-331: I am not convinced by this analysis of ‘coherence across independent variables’.”

We agree that the original wording was too strong. The revised manuscript now refers more cautiously to a consistent pattern across several thermodynamic variables rather than presenting this convergence as definitive attribution evidence.

“Lines 335-343: This whole paragraph belongs to the Methods section.”

We agree and moved the methodological description of the climate variability indices to the Methods section. The revised manuscript now specifies the indices used, their sources, and the statistical framework adopted for the comparisons.

“Lines 360-363: The discussion of the positive AMO phase describes its influence on the regional summer climate, but does not explain how these conditions specifically affect the Mediterranean basin.”

We revised this section substantially. The revised manuscript now presents these climate modes as descriptive background information associated with the analogue populations rather than as demonstrated causal drivers of the event. We also clarified the transitions between the different modes and moderated the interpretation throughout.

“Lines 368-372: Figure 3 only compares the distributions of climate mode indices during analogue dates in past and present periods.”

We agree and revised the wording accordingly. The revised manuscript now explicitly states that the climate variability analysis is descriptive and does not demonstrate causal relationships between these modes and the 2025 event.

“Lines 373-380: This paragraph is not clear or well explained. Rephrase.”

We rewrote this paragraph substantially for clarity.

“Lines 382-383: This is expected, since 2025 falls within the present period rather than the past.”

We revised the wording to avoid overstating novelty and clarified the intended interpretation.

Discussion

“Lines 386-387: The manuscript does not demonstrate that the 2025 MHW is amplified by anthropogenic climate change.”

We substantially revised the Discussion and Conclusions sections accordingly. The revised manuscript now explicitly states that the framework provides an observational and conditional line of evidence consistent with thermodynamic amplification in a warmer climate background, while not constituting a complete formal attribution assessment. We also now explicitly acknowledge that internal variability cannot be fully separated from externally forced trends within the present framework.

“Lines 401-402: I do not agree with the statement that these changes are ‘purely from the climate shift.’”

We agree and removed this wording from the revised manuscript.

“Lines 402-404: It is well established from previous studies using formal attribution methods that Mediterranean MHWs are increasingly likely due to climate change.”

We agree and revised the manuscript accordingly. The revised version now positions the analogue framework as complementary to formal model-based attribution studies rather than as an alternative to them.

“Line 406: The statement ‘Here we can say the same for the marine heatwave of 2025’ is not justified.”

We removed and reformulated this statement in the revised manuscript.

“Lines 420-423: Is the discussion here still about MHWs or more generally about atmospheric or compound heatwaves?”

We clarified the scope of the discussion and revised the wording accordingly.

“Line 426: The claim that a northward shift of the subtropical ridge influenced the 2025 event has not been demonstrated here.”

We agree and now present this interpretation only as a possible hypothesis rather than as a demonstrated mechanism.

“Lines 436-438: The discussion of stationarity is somewhat too strong.”

We agree and revised this section substantially. The revised manuscript now presents stationarity more carefully as an assumption and limitation of the analogue framework rather than as a guaranteed property.

“Line 444: The argument that moderate analogue distances justify using analogues for attribution is not valid.”

We agree and revised this discussion accordingly. The revised manuscript no longer presents analogue similarity itself as a justification for attribution, but rather as a condition supporting physical comparability within the observational framework.

“Lines 447-450: That claim may apply mainly to summer MHWs.”

We agree and clarified explicitly that the discussion refers to summer Mediterranean marine heatwaves. We also strengthened the discussion of omitted ocean dynamical processes.

“Lines 471-472: This point is valid but already noted in the Introduction.”

We removed the repetition.

“Lines 473-474: It is unclear from the text which sources or studies support the statement that the 2025 event likely caused or will cause significant ecological stress.”

We revised this statement and clarified the supporting references.

“Lines 474-475: As with many previous events and studies, higher SSTs naturally lead to more intense MHWs.”

We revised the wording to avoid overstating novelty and now frame the study more explicitly as an event-specific diagnostic analysis.

“Lines 476-477: Once again, this is not a climate change attribution.”

We agree that the original wording was too strong. The revised manuscript now consistently describes the framework as an observational and conditional attribution line of evidence rather than as a complete formal attribution assessment.

“Lines 480-482: You have not demonstrated how the ocean or the atmospheric variables have responded specifically to climate change.”

We agree and strengthened the discussion of limitations accordingly. The revised manuscript now explicitly acknowledges that the framework cannot isolate externally forced trends from internal variability.

“Lines 480-491: The authors’ claim that the 2025 event would have been ‘extremely unlikely’ under pre-industrial conditions is not supported by the methods used here.”

We agree and removed these statements from the revised manuscript. The revised conclusions now avoid unsupported probabilistic claims regarding pre-industrial likelihood and instead present the results more cautiously as evidence consistent with thermodynamic amplification in a warmer climate background.