

Reviewer 1

The manuscript entitled “Marine heatwaves across the central South Pacific: characteristics, mechanisms, and modulation by the El Niño Southern Oscillation” by Bastien Pagli et al., submitted to Ocean Science, investigates the contribution and importance of El Niño Southern Oscillation (ENSO) to marine heatwave occurrences and evolution in the central South Pacific and across French Polynesia.

Overall, I find the manuscript to be a valuable contribution to our understanding of ENSO on marine heatwaves across this region that is sensitive to ENSO phase both temporally and spatially. I recommend the manuscript be potentially acceptable for publication once the comments below have been satisfactorily addressed by the authors.

We would like to sincerely thank the reviewer for their comments and for the time spent reviewing the manuscript, which has improved its readability and content. Please find below our point-by-point responses to the reviewer’s comments. Our responses are shown in blue.

Comments and Concerns

L2: In the title, I recommend deleting “the” as with “the El” it’s like a double-“the”

We thank the reviewer for this comment. Indeed, this can alleviate the title. We deleted “the El”. But we kept the first “the”.

LL18-19: “MHW exposure varies widely across the region” – at this point, the reader is unaware what the authors mean by “exposure” here, which is a term most often used when referring to species and/or ecosystem exposure to a hazard

We thank the reviewer for this comment. Here, the term “exposure” was intended to encompass event intensity, duration, and their combined effect (as represented by the DHW metric). To avoid ambiguity, we have replaced “exposure” with “characteristics.”

L23: “FP” acronym is undefined; delete “of”

We have now defined the FP acronym above at the first mention of “French Polynesia”. We have deleted “of”.

L24: Is there really a “cold season” across French Polynesia?

Although French Polynesia does not experience a true “cold” season, we use the terms cold and warm season here to refer to the austral dry and wet seasons, respectively, during which temperatures are relatively cooler and warmer. For the ocean, surface temperature are warmer during the warm season and colder during the cold season.

L26: change “MHWs occurrence” to “MHW occurrences”, here and throughout the manuscript

We modified accordingly throughout the manuscript.

L33: “known as prolonged periods of extreme ocean temperature” – MHWs are not periods of extreme temperature (which would be measured in time units), but rather they are temperature extremes that persist (measured in temperature units)

We have revised the text accordingly: “Marine heatwaves (MHWs), known as extreme ocean temperature persisting in time, have significant impacts on ...”

LL35-36: “and are projected to continue rising in the future (Oliver et al., 2018)” – this last part of the sentence is not covered by the cited reference which focuses on historical data, and not projections. The authors should cite another reference for this.

We agree with the reviewer’s comment. We have added Oliver et al., (2019).

L36: “Developing skillful ... their impacts.” – This is a leap in a single sentence. It needs to be explained further. Skillful forecasts do not necessarily translate to reduced ecological impacts. We added an explicit causal link between «the improved forecasting » and « the reduction of ecological impacts » by introducing the term “anticipate.”:

“Developing skillful forecasts of MHWs is therefore essential to anticipate their impacts and, in turn, support effective mitigation. »

LL37-38: “Such forecasts ... variability.” – A relevant paper to cite here is Holbrook et al. (2020, NREE) which makes and builds the case for understanding MHW predictability and prediction. We thank the reviewer for this suggestion. The corresponding reference has been added to the manuscript.

L43: “increased MHW” – also include “and suppressed MHW”

We agree with the reviewer’s comment and have added the following text:

“In the South-Central Pacific, El Niño Southern Oscillation (ENSO) with its different phases El Niño (EN) and La Niña (LN) are known to be important drivers of increased and suppressed MHW occurrence (Holbrook et al., 2019, 2022) and MHW intensity (Sen Gupta et al., 2020).”

L45: “(Gregory et al., (2024))” should be “Gregory et al. (2024)”

Corrected

L47: acronym “SST” is undefined

We have now explicitly written « sea surface temperature (SST)”.

L53: “MHWs” should be “MHWs’ “

Corrected

L59 and L64 and throughout: I consider it more appropriate to replace “impacts” with “influences”, since the word “impacts” is more appropriate for socio-ecological impacts, while “influences” is between the physical components

We have changed “impacts” to “influences”.

L81: “OISST” – write in words first and then use the acronym

We first mentioned the full name according to the reviewer’s comment: “Daily SST data were obtained from the Optimum Interpolation Sea Surface Temperature version 2 (OISSTv2) dataset, ...”

L82: delete “resolution” – the data are interpolated to a 0.25o grid, which does not necessarily reflect the true “resolution” of the original sampling

We agree with the reviewer's comment. We have corrected accordingly.

LL88-89: "Due to the known ... ERA-Interim" – why not use ERA5 throughout?

For consistency we have used the forcing fields of GLORYS in the heat budget analysis part. These are described in the text: "In addition, surface heat and momentum fluxes used to force the oceanic model (including the large-scale corrections applied by Lellouche et al., 2021), were analyzed. GLORYS reanalysis is forced by ERA-Interim until 2019 (Dee et al., 2011) and ERA5 afterwards (Hersbach et al., 2020). »

LL138-140: "Whether or not ... Amaya et al., 2023; Capotondi et al., 2024)." – This is not a sentence, please rewrite. Also, note that the Amaya et al. (2023) paper was challenged by Sen Gupta et al. (2023, Nature) and which helped lead to the paper by Smith et al. (2025, Prog Oceanogr). It would be good to reflect this in the manuscript.

See below

LL140-141: "Both approaches are complementary ... address." – The key reference here is Smith et al. (2025, Prog Oceanogr).

See below

LL141-144: Another approach would be to follow the guidance of Smith et al. (2025), as the terminology "total heat exposure" suggests that species are indeed exposed to the hazard. I'm not sure we can absolutely assume that?

We thank the reviewer for the last three comments. We agree that it would be good to include these recent discussions and guidance in the manuscript, as we followed them in the methods. We rephrased this part of the text as follows:

"Removing a long term temperature trend (shown in Fig. S2 for FP region) before applying the detection method is a methodological choice as is the selection of a fixed versus a shifting baseline, both of which can influence the results and their significance (Amaya et al., 2023; Sen Gupta, 2023; Capotondi et al., 2024; Smith et al., 2025). A central question underlying these methodological choices is the definition of the "normal" state against which extreme ocean temperatures are identified. This ambiguity complicates both the definition of MHWs and the communication of MHW-related risks to the public. As a result, considerable discussion has emerged regarding MHW naming conventions and definition (Amaya et al., 2023, Sen Gupta, 2023, Smith et al., 2025). While some disagreement persists in the community regarding the definition of a MHW, it appears that both approaches are complementary, and the most appropriate depends on the specific research question to address (Smith et al., 2025). Here, we followed the guidance of Smith et al. (2025) by explicitly distinguishing MHW events identified using each approach and by clearly stating the motivation underlying the results presented. In the context of a fixed-baseline framework, retaining the long-term trend is particularly appropriate when assessing the impacts of MHWs on ecosystems or organisms with limited adaptive capacity such as coral reef. Conversely, when the focus is on interannual variability, climate-mode relationships, or the physical mechanisms driving MHWs, removing the trend can be advantageous for isolating these signals. For these reasons, the part that describes the MHWs metrics over FP was made without removing the trend (section 3) and the part analyzing the link with ENSO and the mechanisms of MHW was made with detrended SST data (section 4-5). For section 3 ,

complementary results based on detrended SST data—where the MHW detection method and threshold computation were reapplied—are provided in the Supplementary Information (SI). Briefly, detrending does not alter the main results — such as differences between archipelagos, ENSO modulation, dominant mechanisms — but does slightly affect some quantitative MHW characteristics, including their duration, intensity, and onset/decline rates.

L179: acronym “MLD” is undefined

We have explicitly defined mixed-layer depth.

LL184-186: the word “net” should be explicitly used in each term in the equation, e.g. “LHF the net latent heat flux” etc.

We adjusted accordingly in the text.

L191: In Equation (5), why is “dk” used rather than “dt”?

It is to avoid using the same letter for the integration variable and the bounds of the integral. We changed ‘dk’ to ‘d τ ’ to avoid any confusion.

L199: “sea-level (SSH)” – should this be “sea surface height”? Sea level and sea surface height can be subtly different.

We have replaced sea level by sea surface height.

LL210-212: Following the Hobday et al. (2016) definition, why isn’t the average total number of MHW days/year close to 10% of the year (~36/year) everywhere?

Here, MHW days are defined as days for which SST exceeds the 90th-percentile threshold (SST^{90th}) and this condition persists for at least five consecutive days. This duration criterion explains why the number of MHW days is not exactly 10% of the total number of days. Among all days exceeding the SST^{90th} threshold, the fraction that satisfies the five-day persistence requirement varies depending on atmospheric conditions (e.g., wind, air–sea fluxes) and oceanic conditions (e.g., mixed-layer depth, heat advection).

L213: “During the cold season ... compared to the warm season.” – Based on the 90th percentile seasonally varying threshold applied using Hobday et al. (2016), why are there less cold season MHWs than in the warm season?

Based on the previous comment, we suggest that several factors (stronger wind for example) may explain why it is more difficult to satisfy the five-day duration criterion during the cold season than during the warm season and then explain the difference between warm season and cold season MHW days.

L233: “cumulative impacts” should be “cumulative intensities”

We have changed « cumulative impacts » by “cumulative intensities” in the text.

L250: Figure 2 caption – “map”, I think should be “legend”

We thank the reviewer for pointing out this issue. This is an error. This sentence has been removed.

LL273-274: “However some differences ... than in OISST.” – This is consistent with the analysis of Pilo et al. (2019) based on ACCESS-OM2 simulations across different model resolutions. I suggest this would be an appropriate reference to cite as context.

The study by Pilo et al. (2019) is now cited, and we have now added it to the main text : « However some differences can be seen, detected MHWs are generally longer and weaker in GLORYS than in OISST in agreement with (Pilo et al., 2019; Chevillard et al., 2025)”

L394: Figure 6 choice of colorbar for panels a-c and e-g make it difficult to discern proportions <40%.

We thank the reviewer for noting that. We have changed the colormap in order to better discern proportions <40%.

L542: Conclusions section usually follows the Discussion section.

We have moved the conclusion section after the discussion.

L568: I think “types” would be better used to replace the terminology of “categories” in the context used here, as “categories” is typically reserved for measures of MHW intensity.

We have modified the text accordingly.

LL605-606: Another earlier study of MHWs in the region and relevant reference here is Holbrook et al. (2022, Glob Planet Change).

We have added this reference.

L632: “Gupta and Sil (2024)” should be “(Gupta and Sil, 2024)”

We have corrected accordingly.

References

Holbrook NJ et al., 2022: Impacts of marine heatwaves on tropical western and central Pacific Island nations and their communities. *Global and Planetary Change*, 208, 103680, <https://doi.org/10.1016/j.gloplacha.2021.103680>.

Holbrook NJ et al., 2020: Keeping pace with marine heatwaves. *Nature Reviews Earth and Environment*, 1, 482-493, <https://doi.org/10.1038/s43017-020-0068-4>.

Sen Gupta A et al., 2023: Marine heatwaves: definition duel heats up. *Nature*, 617, 465, <https://www.nature.com/articles/d41586-023-01619-4>.

Smith KE et al., 2025: Baseline matters: Challenges and implications of different marine heatwave baselines. *Progress in Oceanography*, 231, 103404, <https://doi.org/10.1016/j.pocean.2024.103404>.

Pilo G S et al., 2019: Sensitivity of marine heatwave metrics to ocean model resolution. *Geophysical Research Letters*, 46, 14604-14612, doi:10.1029/2019GL084928.

References

Oliver, E. C. J., Burrows, M. T., Donat, M. G., Sen Gupta, A., Alexander, L. V., Perkins-Kirkpatrick, S. E., Benthuisen, J. A., Hobday, A. J., Holbrook, N. J., Moore, P. J., Thomsen, M. S., Wernberg, T., and Smale, D. A.: Projected Marine Heatwaves in the 21st Century and the Potential for Ecological Impact, *Front. Mar. Sci.*, 6, 2019.