Revision of manuscript **sp-2024-31**

This paper investigates the horizontal and vertical intensity and propagation of the 2023 MHW in the North Atlantic upper water column. While the study contains some interesting findings, the lack of clarity and rigour in the explanations and interpretations detracts from its overall impact. The manuscript is difficult to read and understand in several parts.

The Methods section needs to be more rigorously worded, and all calculations listed in the manuscript need to be explained.

The Results need to be improved and appropriate references to figures should be made at the appropriate points in the text to facilitate understanding and strengthen the link between the text and Figures.

The paragraph "Characterisation of Marine Heatwave" should be revised to clearly explain the rationale for the methodological choices and how these choices improve the plausibility and reliability of the results. Providing this context will not only improve readability but also enhance the scientific credibility of the paper.

We thank the reviewer for the very useful feedback to improve the manuscript. We have taken them into account to enhance clarity and rigor. As requested, the method section was fully rewritten to better express our goal. Figure were better quoted in the results section to improve the readability and understandings.

Specific Comments:

Line 47: "MOI weekly bulletin", add a link or a reference.

Link was added in the introduction.

Line 51: add references to justify the sentence: "Furthermore, MHW have been well studied for the surface where long satellite records exist, but description and understanding 51 of their vertical structure remains incomplete."

The sentence has been modified and now states that 'the subsurface extent should be considered more in details' to better reflect the current state of the art. We also added the following references to Zhang et al. 2023, Schaeffer et al. 2023 and Sun et al. 2023 in the revised manuscript to support this.

Zhang, Y., Du, Y., Feng, M., and Hobday, A. J.: Vertical structures of marine heatwaves, Nat Commun, 14, 6483, https://doi.org/10.1038/s41467-023-42219-0, 2023

Schaeffer, A., Sen Gupta, A., and Roughan, M.: Seasonal stratification and complex local dynamics control the sub-surface structure of marine heatwaves in Eastern Australian coastal waters, Commun Earth Environ, 4, 1–12, https://doi.org/10.1038/s43247-023-00966-4, 2023.

Sun, D., Li, F., Jing, Z., Hu, S., and Zhang, B.: Frequent marine heatwaves hidden below the surface of the global ocean, Nat. Geosci., 16, 1099–1104, https://doi.org/10.1038/s41561-023-01325-w, 2023.

Line 52: add references to Juza et al. (2022) and Pirro et al. (2024)

Juza M, Fernández-Mora À and Tintoré J (2022) Sub-Regional Marine Heat Waves in the Mediterranean

Sea From Observations: Long-Term Surface Changes, Sub-Surface and Coastal Responses. Front. Mar. Sci. 9:785771. doi: 10.3389/fmars.2022.785771

Pirro, A., Martellucci, R., Gallo, A., Kubin, E., Mauri, E., Juza, M., Notarstefano, G., Pacciaroni, M., Bussani, A., and Menna, M.: Subsurface warming derived from Argo floats during the 2022 Mediterranean marine heat wave, in: 8th edition of the Copernicus Ocean State Report (OSR8), edited by: von Schuckmann, K., Moreira, L., Grégoire, M., Marcos, M., Staneva, J., Brasseur, P., Garric, G., Lionello, P., Karstensen, J., and Neukermans, G., Copernicus Publications, State Planet, 4-osr8, 18, https://doi.org/10.5194/sp-4-osr8-18-2024, 2024.

We thank the reviewer for pointing to these valuable studies and added both references intpo the revised manuscript

Lines 52-58, Pag 2: I take a different view of this statement. For example, Juza et al. (2022) and Pirro et al. (2024) have successfully used SeaDataNet climatology to derive anomalies from Argo float profiles without encountering problems related to 'incomplete reconstruction'. Could you please elaborate on this point and provide additional explanation? In particular, what factors lead to the conclusion that modelling products are more suitable for defining and detecting MHWs than in-situ data?

To rigorously evaluate this claim, a detailed comparison between the 3D model output and in-situ data during a well-documented MHW event is essential. Such a study would assess the ability of the model to reproduce the observed trends, particularly in terms of intensity, duration and spatial variability. A key question is whether the model accurately represents the observed dynamics or whether it oversmooths the data, potentially underestimating localised extremes.

We thank the reviewer for his/her comment, we have removed the sentence which appeared to oppose approaches and was misleading.

We believe both approaches (use of data-assimilating modelling products and in-situ data) are complementary, we chose to use modelling-based products to be able to build a daily 30-year climatology at surface and subsurface and for every grid cell. This choice is mainly motivated by the recommendations of the WMO to use a 30-year climatology when possible and the recommendations of Hobday et at. 2016, 2018 (used for MHW definition). Also, it is important to keep in mind that we didn't use a model product (e.g. a free run model resulting from solely resolving the equations of state) but a reanalysis one which is constrained by data (in situ and satellite-driven), and as such is close to the observation derived data.

Pag 4, Lines 85-90: Which layer did you use to define the occurrence of MHW and apply the method of Hobday et al. 2026? Did you use only the first layer of the model (surface layer) or the 0-200 m layer? Please clarify.

The method of Hobday et al. 2016 was used for the surface layer of GLORYS12V1 reanalysis (thickness of 1m) from 1993 to 2023 and used for all GLORYS12V1 layers from surface to 2,200m for the year 2023. Sentences were added to clarify this aspect lines 90-93.

Pag 4, Lines 90-92: This sentence is rather unclear and raises questions about the authors' methodology and aims. Why did the authors estimate the MHW for the entire water column in 2023, but limit their analysis to the surface layer for the period 1993–2022? What was the purpose of these different approaches? The reasons for these estimates are not clearly explained, leaving the reader uncertain about the authors' goals and the reasons for their choices.

We first detected MHWs at the surface for 2023 and also from 1993 to 2022 to compare the 2023 surface characteristics with those of previous year. This first part allows us to claim the exceptional 2023 event for the surface. Once the surface 2023 event was characterized, we extended the study to subsurface to understand the mechanisms.

Method section was fully rewritten for clarification and further explanations.

Introduction and Line 35, Pag:5: There was also a marine heatwave in 2021 and 2022 in the North Atlantic and the Mediterranean (e.g. https://www.mercator-ocean.eu/en/news/state-of-the-climate-inhttps://www.mercator-ocean.eu/en/news/state-of-the-climate-in-europe-2022-report-2/europe-2022-report-2/). Include these events in the introduction and relate it to that of 2023. Could it be the occurrence of these earlier events that intensified the MHW of 2023?

This previous events could have indeed played a role in the intensity of the 2023 event. Nevertheless, it is complicated to disentangle the initial condition and atmospheric influence with only one occurrence. Moreover, we estimated the start of the event in spring (Figure 1b) and we distinguish peaks and increase in intensity as from March in the time series (Figure 3 b, c & d), making this event and the ones from 2020 and 2021 separate ones. This study focuses on the 2023 event and its characteristics.

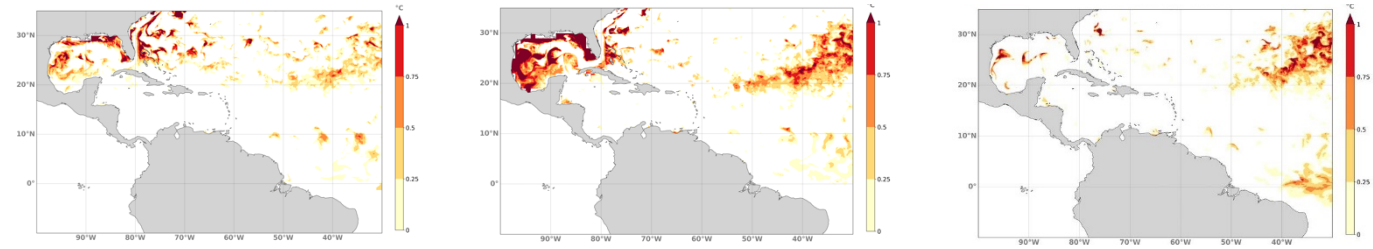
Even thought, we acknowledge your claim that these previous MHW from 2020 and 2021 might have played a role in the 2023 event, we chose not to mention them to avoid any confusion for the reader as we don't analyze this potential role later in the study.

Figure 3a: The difference in colour between NASE (brown) and CARB (red) is too difficult to see in the legend. Why not use less similar colours?

Colors were changed to better differentiate NASE & CARB.

Pag 8, Line 78: There is also a peck (absolute maximum) in March in the CRAB region but no comment on it in the text.

This peak in March was mentioned later in the result section. We now mention it earlier and added an extra sentence in the revised manuscript. It seems to come from MHWs trapped by the loop current in the Gulf of Mexico that peak mid-March and quickly disappear (see intensity maps below). This is an independent event which would require another study.



MHW Intensity map 2023-03-03 (a), 2023-03-13 (b), 2023-03-23 (c)

Pag 9, Lines 81-94: This paragraph is very difficult to follow for a number of reasons: the relative figures are not quoted in the text and/or are quoted incorrectly (this applies to the entire results section); the depths of the layers quoted in the text do not coincide with those in Figure 3 (e.g. 100 m in the text and 156 m in the figure); the references to MLD are incomprehensible as the MLD is not shown in any of the figures.

The quotes were corrected for the entire results section.

The quoted depths correspond to the layer in the figure. We mentioned 100m which is not shown in Figure 3 but we can see in the time/depth Hovmöller (figure 4e) which is quoted.

The MLD is shown in Figure 3a and Figure 4e and we added its temporal evolution in each subregion in Figure 3b, c & d. We added a sentence in the revised method section and in figure description for clarifications. We also expended comments on the MLD in the results sections.

Pag 9, Line 96: "The evolution of the mean intensity for NATR describes…" In which layer?

This sentence refers to the evolution throughout the water column we can see on Figure 3a (intensity profile), and especially for the layers shown in the time series of Figure 3c. We added 'at the surface and at depth' for clarification.

Pag 10, Lines 22-38: If this map was created by averaging the selected areas in latitude, how did you manage the overlap in longitude of the NASE and NATR sections? If I look east of 40°W, am I looking at NATR, NASE or both?

Thank the reviewer for highlighting the lack of clarity on this point. When sections overlap in longitude, the data from both sections are averaged together. We specified this aspect when rewriting the revised method section.

Pages 10-11: How were all the velocities estimated on these pages (lines 36, 51, 58) There is no reference to velocities in the methods.

Velocities were roughly estimated based on the slope of diagonals formed by intensity in Hovmöller diagrams. This provides an estimate of the order of magnitude of the velocities, but it is not intended to represent an exact value. Explanations were added in the revised manuscript.

Figure 4f: What is the meaning of the blank areas in Figure 4f? Is it the lack of data? Why is it that when you use a model there is no data in some areas? Could you please describe this figure better, explain how it was made and how it should be interpreted?

Figure 4f represents the intensity of MHWs at 156m depth on the 7th of July 2023, thus it only shows areas where MHW were detected in the Atlantic Ocean. Blank areas mean that no MHW were detected there for that day. The Pacific Ocean is blank as well as it is out of the studied area. A sentence was added in the revised manuscript to clarify this aspect.