

Response to Referee #1

Manuscript egusphere-2026-2571, *Seasonal and spatio-temporal dynamics of marine heatwaves in the Senegalo–Mauritanian upwelling system and chlorophyll-a responses*

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The MATLAB scripts, functions and processed data used in this study, including the MHW event catalogues, are archived on Zenodo: <https://doi.org/10.5281/zenodo.23505759>.

Note: I wrote these comments in a markdown editor and pasted them here; some markdown remains in places.

General comments

This study addresses a worthwhile question, which is, how do marine heatwaves differ among the permanent and seasonal upwelling regions of the Senegal–Mauritania coast, and what chl-a anomalies accompany them? The long SST record, regional comparisons, and separation of cooling and warming periods provide a useful basis for answering this. The seasonal reversal in chl-a anomalies at Cap Blanc is interesting. The subject fits Ocean Science, and the regional analysis could contribute if the results and their interpretation are better substantiated.

The main challenge is that the manuscript goes too quickly from associations among SST, winds, upwelling indices, and chl-a to quite specific explanations of circulation, nutrient supply, and phytoplankton growth. Several of those explanations are not established by the measurements. Most consequentially, negative anomalies in the thermal upwelling index are treated as evidence that upwelling has “collapsed”. The index is itself partly determined by the coastal SST used to identify heatwaves, and an anomaly below zero does not mean that the underlying index is below zero. The distinction between a northern regime dominated by surface heat exchange and a southern regime dominated by ocean dynamics also needs stronger support. These interpretations underpin much of the abstract and conclusion.

The manuscript also has further problems with event selection, composite uncertainty, seasonal comparisons, and reproducibility. Some statements contradict the reported results, including the assertion that Cap Blanc is stable across all indicators. The presentation is generally understandable, but repeated mechanistic explanations and an extended conclusion obscure the distinction between observations and proposed explanations.

***I recommend major revision.** The spatial and seasonal descriptions are potentially valuable, but the central mechanistic claims need either additional analysis or substantial qualification before we can accept them. My five comments below point to the main work required; several could change the conclusions, so they should be resolved before rewriting the abstract and discussion.*

Response. We thank the referee for this careful and constructive assessment, which led to a thorough revision of the manuscript. We have addressed each of the points raised, as detailed in the responses below.

Following the main comment, the manuscript now clearly distinguishes the observed associations from the proposed mechanisms, the latter being presented as hypotheses. Explanations involving nutrient supply, photosynthetic efficiency and phytoplankton growth, which are not supported by our data, have been removed or rephrased (comment 3). Negative CUI anomalies are no longer interpreted as a collapse of upwelling: the CUI is shown as absolute values, climatology and anomalies, its coastal and offshore contributions are separated, and its evolution is compared with that of wind and EPV (comment 1).

The distinction between a northern regime dominated by air–sea fluxes and a southern regime dominated by ocean dynamics has been re-examined with a mixed-layer heat budget computed from GLORYS12V1. This budget shows that warming during onset is mainly associated with oceanic terms in all three sub-regions, air–sea fluxes playing a larger role in some seasons and during MHW decline; the opposition between the two regimes has therefore been removed from the abstract and the conclusion (comment 1).

The other points have also been addressed: event selection and overlap, composite uncertainty (comment 2), seasonal comparisons and trends, including their sensitivity to exceptional years and to the baseline period (comment 4), and reproducibility, with the description of the regional masks and the archiving of the scripts and event catalogues (comment 5). The statement that Cap Blanc is stable for all indicators has been removed. Finally, the abstract and the conclusion have been rewritten and shortened, and a paragraph on the limitations of the study has been added.

Specific comments

1. 1.195–204, 224–234, 399–447, 465–497, and 526–549: How do we know that upwelling collapses?

Figures 7e and 8e show CUI anomalies. However, negative values are repeatedly interpreted as a breakdown or near-complete cessation of upwelling. These are different statements. Appendix A reports positive cooling-season CUI values of approximately 1.5–2.0 °C in the southern regions. An anomaly of –0.5 °C could therefore leave a substantial positive coastal–offshore temperature difference. Please show the absolute index and the corresponding event-date climatology alongside its anomaly, then reassess the descriptions of persistent, weakened, and collapsed upwelling. Even an absolute thermal-index reversal would require care when interpreted as a circulation reversal.

The calculation also depends on the choice of reference. From Eq. (3), $CUI' = SST'_{\text{offshore}} - SST'_{\text{coast}}$, so selecting events with unusually high coastal SST can produce negative CUI anomalies without independently demonstrating a reduction in vertical transport. Please separate the coastal and offshore SST contributions and support the circulation interpretation with an independent diagnostic. An alongshore wind-stress/offshore Ekman-transport index would be useful here. Wind-stress curl measures Ekman pumping, but it does not by itself represent all coastal upwelling driven by offshore transport at a coastal boundary. Likewise, a wind-speed anomaly does not fully describe changes in the upwelling-favourable wind component.

Response. We thank the referee for this comment. A negative CUI anomaly demonstrates neither a collapse nor a cessation of upwelling (Fig. R1). Moreover, because the CUI depends on the coastal SST used to detect the MHWs, this anomaly alone is not sufficient to establish a reduction in upwelling transport; we have therefore complemented it with an independent dynamical diagnostic (see below). A coast colder than the offshore ocean ($CUI > 0$) is the classical surface signature of coastal upwelling (Sylla et al., 2019, 2022; Fig. A8). The CUI is, however, sensitive to other processes, in particular to the heat fluxes that warm the upwelled waters (Sylla et al., 2019). We therefore now interpret it, in anomalies as in the rest of the paper, as the evolution of the coast–offshore SST contrast over the MHW life cycle (Fig. R1). During the cooling period at Cap Blanc, this contrast remains close to normal as MHWs approach and decreases only at onset, by about half as much as in the south. At Grande Côte and Petite Côte, in contrast, it decreases strongly as soon as MHWs approach. This evolution is consistent with that of Chl-a, with a positive anomaly at Cap Blanc and a negative anomaly in the south (Fig. 10).

Changes in the manuscript: replacement of the terms “collapsed” or “interrupted” (l. 568–571); Sect. 2.4.2 (CUI: definition and limitations); Sect. 3.3; references.

Coastal and offshore contributions. Following the referee’s suggestion, we decomposed $CUI' = SST'_{\text{offshore}} - SST'_{\text{coast}}$ (Fig. R2), using the SST series at the coastal and offshore points used for the CUI (Fig. A8), each expressed as an anomaly relative to its own climatology. Both terms warm during MHWs, and the offshore ocean does not cool. When the coastal warming associated with shelf MHWs exceeds the offshore warming, the coast–offshore SST contrast decreases, leading to a weakening of the surface signature usually associated with upwelling. During the cooling period at Cap Blanc, the coast and the offshore ocean warm similarly as MHWs approach, so that this signature is maintained until onset, when the coast warms about twice as much as the offshore ocean. At Grande Côte and Petite Côte, in contrast, the coast warms about twice as much as

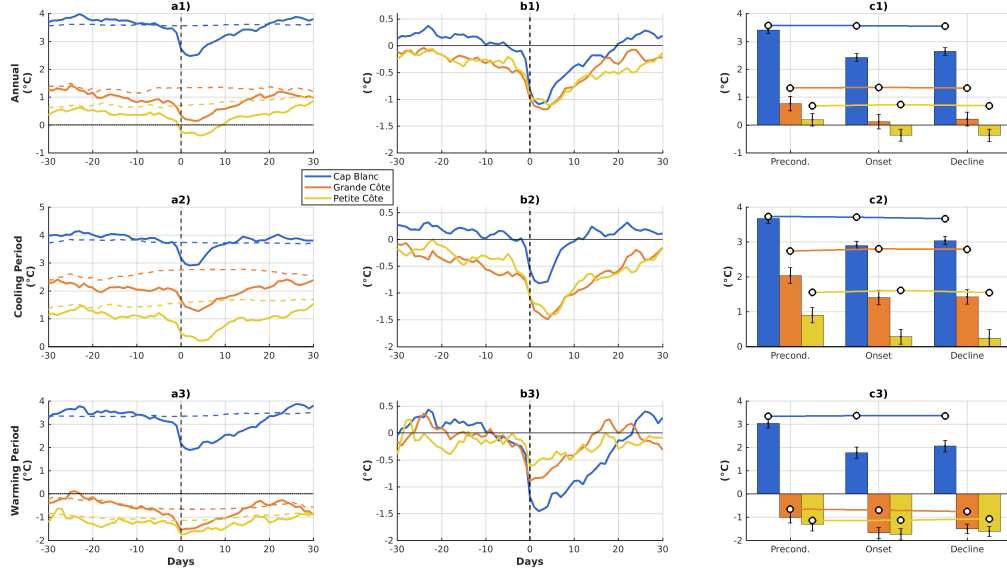


Figure R1: Absolute CUI (solid lines) and climatology at the same dates (dashed lines) around MHW onset (a1–a3), CUI anomaly (b1–b3) and phase averages (c1–c3; bars: absolute CUI, circles: climatology) at Cap Blanc, Grande Côte and Petite Côte, for the whole year, the cooling period and the warming period (1998–2024).

the offshore ocean from three weeks before onset, and the surface signature of upwelling gradually weakens.

Independent dynamical diagnostic. We complemented this analysis with a dynamical diagnostic independent of SST, the upwelling index of Zhan et al. (2024), based on the CUTI of Jacox et al. (2018): $UI = U_{Ek} + U_{geo}$. The Ekman term, U_{Ek} , is computed from the alongshore wind component, not from wind speed. The geostrophic term, U_{geo} , represents the cross-shore transport driven by the alongshore sea-level gradient: when directed onshore, it limits upwelling (Marchesiello and Estrade, 2010), as shown in the SMUS (Ndoye et al., 2017; Sylla et al., 2019). In all three sub-regions, the UI decreases at MHW onset, together with the relaxation of the trade winds and the decrease in EPV (Fig. R3c–e). Its anomalies are dominated by the Ekman term, and its strongest decrease occurs at Cap Blanc, where the wind relaxation is most pronounced. This independent diagnostic confirms that the decrease in the coast–offshore SST contrast during MHWs is accompanied by a reduction, not a cessation, of upwelling transport, and that it does not result only from the selection of events on coastal SST. The thermal contrast, in contrast, behaves differently: at Cap Blanc, despite the strongest reduction in dynamical forcing, the CUI decreases less than in the south, indicating that the permanent upwelling there better maintains the supply of cold water.

UI computation. Daily GLORYS12V1 sea surface height and mixed-layer depth fields ($1/12^\circ$, 1993–2024) were interpolated (bilinear interpolation) onto the OISST grid (0.25°), used for MHW detection and for the other indices. At each latitude, the coastal point is the easternmost ocean grid cell. As in Jacox et al. (2018) and Zhan et al. (2024), ΔSSH is the sea surface height difference between two coastal points 1° of latitude apart, here located 0.5° north and 0.5° south of each latitude, and d_{coast} is the distance between these two points. The mixed-layer depth and the cross-shore Ekman transport, $U_{Ek} = -\tau_y / (\rho_w f)$ (ERA5), are averaged over the shelf grid cells (0–200 m) of each latitude. The UI of each latitude is assigned to all grid cells of that latitude, as for the CUI, and then averaged over the shelf of each sub-region. As shown by the composites around MHW onset (Fig. R3), the UI decreases together with wind speed and EPV in all three

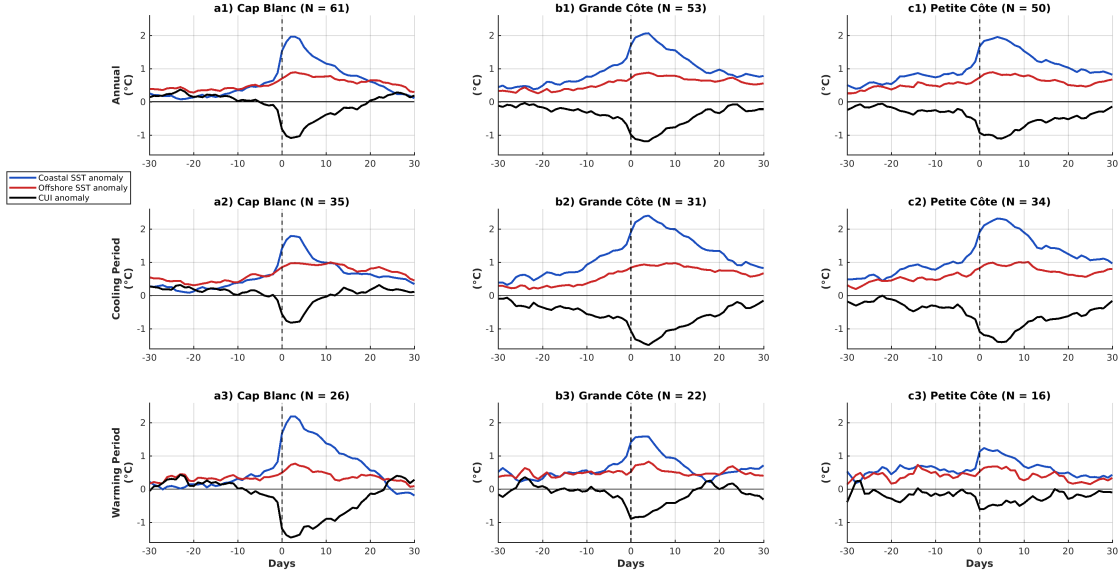


Figure R2: Coastal (blue) and offshore (red) SST anomalies and CUI anomaly (black) around MHW onset, for each sub-region (columns) and for the whole year, the cooling period and the warming period (rows); N : number of events.

sub-regions: the decrease, brief and centred on onset, is strongest at Cap Blanc for the three indicators, where the wind relaxation is most pronounced. Its variations are dominated by those of the Ekman transport. Since the UI provides no information independent of the wind relaxation and the EPV, we did not retain it in the revised manuscript, where wind and EPV remain the dynamical indicators; it is presented here in response to the referee's request.

The heat-flux analysis needs the same distinction between an indicative association and an established/quantified mechanism. At l.391–398, the approximate heat-budget calculation suggests that ocean processes dominate warming in all three regions. The abstract and conclusion nevertheless describe Cap Blanc as thermodynamically dominated. Please quantify the surface-flux contribution separately during development and decay, integrate the flux over explicitly defined intervals, and report the assumed mixed-layer depth and its sensitivity. For scale, 20 W m^{-2} sustained for five days would warm a 20 m layer by about $0.11 \text{ }^{\circ}\text{C}$, using seawater density 1025 kg m^{-3} and heat capacity $3990 \text{ J kg}^{-1} \text{ K}^{-1}$. This shows why the integration interval and mixed-layer depth must be considered. Differences in composite peak height or recovery time do not indicate/reveal which heat-budget term dominates.

The acknowledgement at l.228–234 that this is not a full mixed-layer heat budget is appropriate, but then the subsequent claims need to respect that limitation. An acceptable revision could keep the observed associations and describe the mechanisms as hypotheses. If you retain the strong attribution, you also need stronger heat-budget evidence. Sala et al. (2025), Leading dynamical processes of global marine heatwaves in an ocean state estimate (and cited refs.), provide a relevant Ocean Science example of quantifying contributions during MHW onset/decline; however, this is not a requirement to reproduce that particular modelling approach, and I am showing this FYI.

Response. We thank the referee for pointing out this inconsistency. The order-of-magnitude calculation has been replaced by a mixed-layer heat budget computed from GLORYS12V1, with ERA5 surface fluxes (Sect. 2.4.3). The budget separates, in anomalies, the air–sea flux term (Q), horizontal advection (HADV) and a residual term (RES) that groups the vertical processes. The mixed-layer depth is no longer assumed: it varies daily and is taken from GLORYS12V1 (Fig. A13), which makes a sensitivity test to a fixed value unnecessary. The terms are averaged over three explicitly defined phases: preconditioning (days -3 to -1), onset (start to peak) and decline (day after the peak to the end) (Sect. 2.5.3). The contribution of Q is therefore quantified

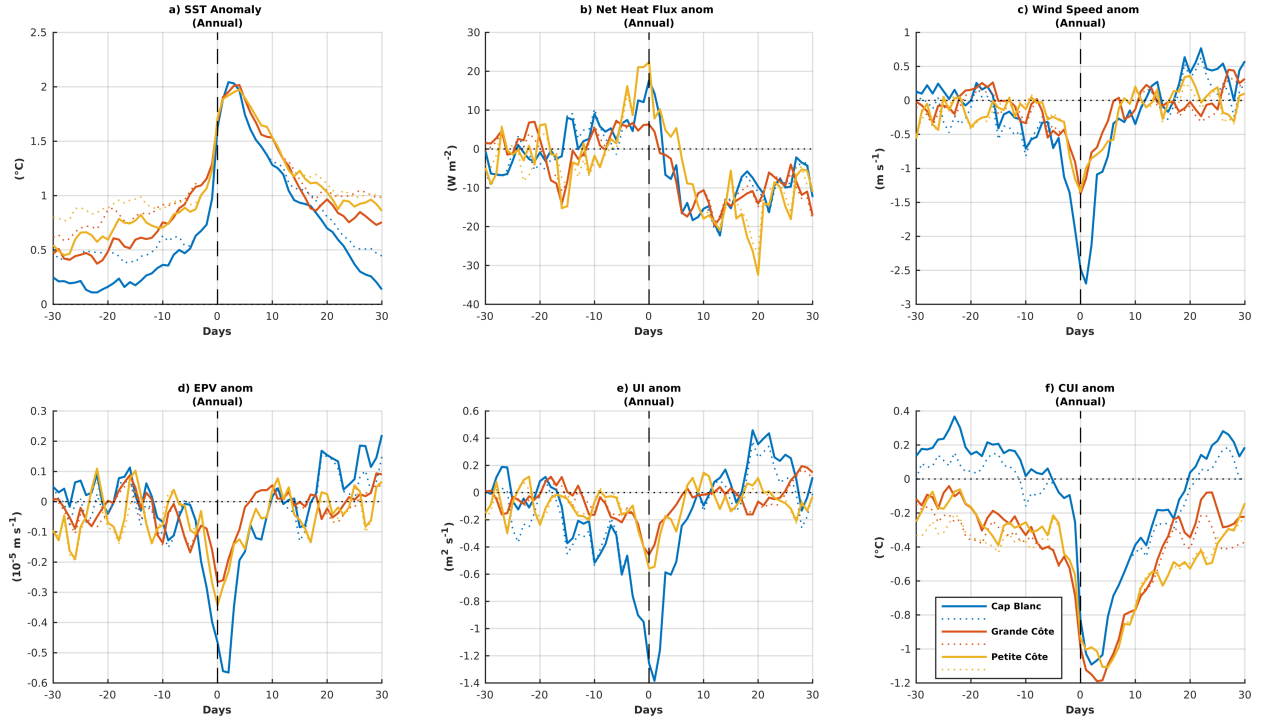


Figure R3: Composite anomalies around MHW onset (1998–2024) in the three SMUS sub-regions (as Fig. 7 of the revised manuscript, with the UI added): (a) SST ($^{\circ}\text{C}$), (b) net heat flux (W m^{-2}), (c) 10 m wind speed (m s^{-1}), (d) EPV (10^{-5} m s^{-1}), (e) UI ($\text{m}^2 \text{ s}^{-1}$) and (f) CUI ($^{\circ}\text{C}$), over 30 days before and after onset (day 0, dashed vertical line). Solid lines: composites excluding days belonging to another MHW; dotted lines: all days. Cap Blanc (blue), Grande Côte (orange) and Petite Côte (yellow).

separately for each phase. The dominant term is identified event by event, following Sala et al. (2025), and not from the height of the composite peak (Fig. 9; Tables A2–A4). The budget shows that the oceanic terms dominate onset in all three sub-regions. The statement that Cap Blanc is “thermodynamically dominated” was therefore incorrect; it has been removed from the abstract and conclusion.

5. 1.107–148, 179–204, 385–387, 554–565, and 698–705: Verify the spatial calculations and provide the analysis workflow.

Please provide the exact regional masks, their areas, and the number of wet grid cells; the bathymetric dataset; and an explanation of how you selected cells shoreward of the 200 m isobath. Cap Blanc is defined as 20.8–22° N in the methods and Figure 1, but 20–22° N in Tables 1–2 and Appendix A. This affects whether part of the excluded Banc d’Arguin sector is included in the analysis. Specify the coastal and offshore sampling bands for CUI, including how the 5° westward displacement follows the coastline and how missing or land-adjacent cells are treated.

Response. We thank the referee. The GEBCO 2024 bathymetry was interpolated onto the OISST grid (0.25°), and only continental-shelf cells (between 0 and -200 m) are retained, before any spatial averaging. The three sub-regions are analysis domains defined to distinguish contrasting upwelling regimes, not geographical entities with predefined boundaries: Cap Blanc ($20.8\text{--}22.0^\circ\text{N}$; 12 cells, $8\,601\text{ km}^2$), Grande Côte ($14.8\text{--}19.2^\circ\text{N}$; 31 cells, $22\,777\text{ km}^2$) and Petite Côte ($12.5\text{--}14.7^\circ\text{N}$; 19 cells, $14\,213\text{ km}^2$) (Fig. R4). The mention of $20\text{--}22^\circ\text{N}$ for Cap Blanc in Tables 1–2 and Appendix A was an error and has been corrected: all scripts use $20.8\text{--}22^\circ\text{N}$, which excludes the Banc d’Arguin sector. The northern boundary of Petite Côte has been harmonised to 14.7°N in the text and Fig. 1. At 0.25° , the shelf is represented by only 12 to 31 cells per sub-region; this resolution limitation is discussed in point 5.3. For the CUI, the coastal point is the last valid ocean cell at each latitude, and the offshore point is located 5° of longitude farther west, with a tolerance of 1° if this point is missing (Fig. A8).

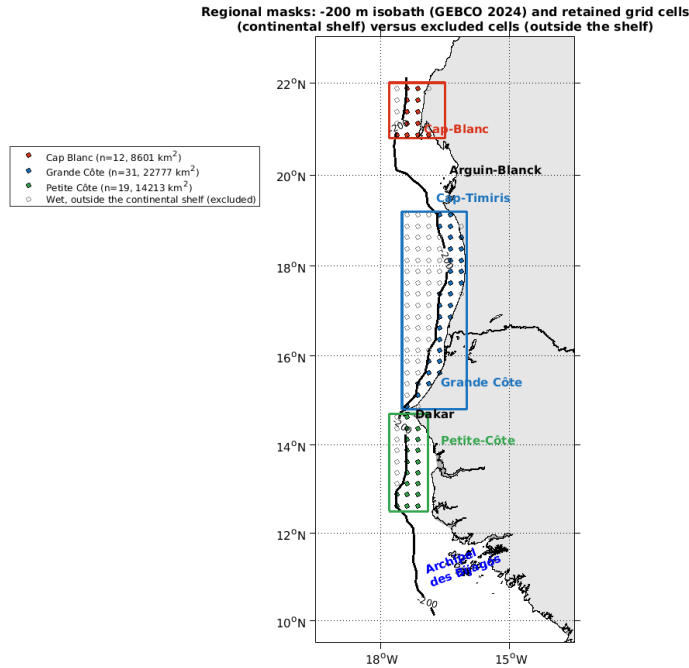


Figure R4: Regional masks: -200 m isobath (GEBCO 2024), retained continental-shelf cells (colours) and excluded cells outside the shelf (open circles).

While reviewing Figure 1, I noticed a discrepancy between the spelling of place names in the Figure and in the text. Ensure they are correctly spelt (or a consistent spelling applied) both in the text and anywhere in Figures/Tables. Further, ensure that all place names in the text also appear in Figure 1.

Response. We thank the referee. The only inconsistency between Fig. 1 and the text concerned the Bijagós Archipelago: the figure carried the French label “Archipel des Bijagós”, whereas the text reads “Bijagós Archipelago”. The figure label has been corrected to “Bijagós Archipelago”. The other place names in Fig. 1 (Cap Blanc, Banc d’Arguin, Cap Timiris, Grande Côte, Petite Côte) are spelt in the same way in the text, figures and tables. All place names used to describe the study area and the sub-regions appear in Fig. 1.

A 0.25° grid represents roughly 25–28 km here and may resolve some shelf sectors with very few cells. Bilinear interpolation of 4 km chl-a onto that grid does not calculate a mean over each coarse cell. Please test whether the principal coastal and regional chl-a results persist with area-based aggregation of valid ocean pixels, or averaging within common regional masks at native resolution. Likewise, matching nominal grid spacing does not establish matching effective resolution of SST and reanalysis winds. Discuss what these products can resolve about the coastal fronts and wind structure used in the interpretation.

Response. We acknowledge that bilinear interpolation of the 4 km chlorophyll-a product onto the 0.25° grid does not constitute an area-based aggregation of the native pixels. To assess the influence of this procedure on our results, we performed an additional sensitivity test. The chlorophyll-a statistics were recomputed directly from the valid pixels at their native resolution (4 km), within the same regional masks. The results were then compared with the composites obtained after interpolation onto the 0.25° grid.

As shown in the new Fig. R5, both approaches give very similar temporal evolutions in the three sub-regions and for the two seasonal periods. The main characteristics of the responses, in particular their sign, amplitude and evolution around MHW onset, are preserved. This test thus confirms that the results presented do not depend substantially on the bilinear interpolation onto the 0.25° grid.

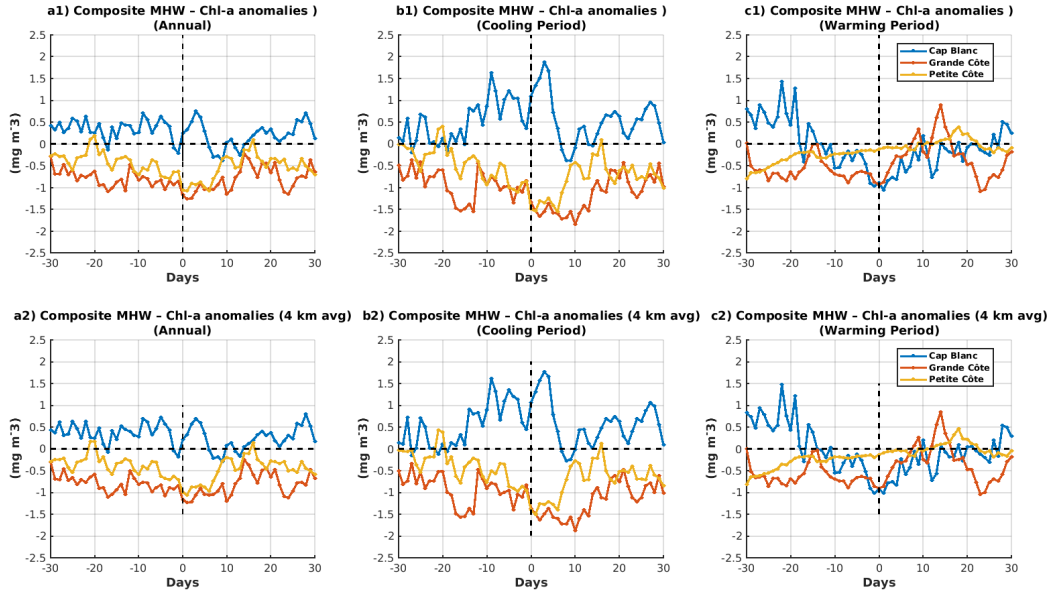


Figure R5: Composites of Chl-a anomalies around MHW onset, computed after interpolation onto the 0.25° grid (a1–c1) and from the valid pixels at the native 4 km resolution (a2–c2), for the whole year, the cooling period and the warming period.

The EPV units and magnitudes need to be checked directly against the calculation. Figure 7d is labelled in 10^{-5} m s^{-1} , while its caption specifies 10^{-6} m s^{-1} ; ditto for Figure 8. Appendix A reports $40\text{--}47 \times 10^{-5} \text{ m s}^{-1}$ during winter at Petite Côte, equivalent to about $35\text{--}41 \text{ m day}^{-1}$. The event anomalies of $0.2\text{--}0.4 \times 10^{-5} \text{ m s}^{-1}$ quoted at 1.386 would be approximately 0.4–1% of those winter values, rather than 10%. These comparisons do not identify the source of the discrepancy, but they do show a problem somewhere. Please verify derivative distances in metres, longitude scaling with latitude, array orientation, coastal differences, and the powers of ten used in plotting. Equation (2) is the constant- f curl approximation; explain its use across this latitudinal domain or assess the effect of using $\text{curl}(\tau/f)/\rho$ instead.

Response. We thank the referee for this detailed check. We repeated the EPV calculation point by point. Distances between cells are computed in kilometres, with a zonal step that accounts for $\cos \varphi$, and then converted to metres; derivatives are taken along the correct axes (longitude for $\partial\tau_y/\partial x$, latitude for $\partial\tau_x/\partial y$); the Coriolis parameter $f = 2\Omega \sin \varphi$ is evaluated at the latitude of each cell. The fields are expressed in m s^{-1} and multiplied by 10^5 for display only. Near the coast, where the centred difference would involve a land cell, the EPV is set equal to that of the neighbouring ocean cell. This treatment, identical for the climatology and the events, does not affect the composite anomalies.

Figs. 7d and 8d are therefore indeed in 10^{-5} m s^{-1} ; their captions, which stated 10^{-6} , have been corrected. The values of $40\text{--}47 \times 10^{-5} \text{ m s}^{-1}$ in Appendix A were wrong. The figure was recomputed from the same EPV field as the composites: its spatial and seasonal structure is unchanged, only the values change. At Petite Côte, the winter EPV is about $1.1\text{--}1.2 \times 10^{-5} \text{ m s}^{-1}$, i.e. about 1 m day^{-1} (Fig. A1b2). The erroneous comparison (“about 10%”) has been removed from the text.

Finally, Eq. (2) neglects the variation of f with latitude inside the derivative. The full formulation, $\text{curl}(\tau/f)/\rho$, adds the term $\beta\tau_x/(\rho f^2)$. For the winter trade wind, this term is about $-0.05 \times 10^{-5} \text{ m s}^{-1}$, i.e. about 5% of the EPV, and changes neither the sign nor the spatial and seasonal structure of the results.

*The public source datasets and an unmodified detection toolbox do not reproduce the complete study. Please archive the scripts for preprocessing, masks, indices, event selection, seasonal allocation, composites, statistical analysis, and figures, together with a dated software version and the derived event catalogue. Identify the exact functions used for trend estimation. If the toolbox’s `mean_and_trend.m` was used, its currently available source uses MATLAB regression for trend estimates; it does not by itself implement the Mann–Kendall/Sen procedure described here. I am more concerned that you identify the study’s implementation than that you provide evidence that this particular routine was used. I also think the journal’s data policy requires access to the data needed to **replicate** figures.*

Response. We thank the referee. All the MATLAB scripts of the study (preprocessing, regional masks, upwelling indices, MHW detection and seasonal allocation, composites, heat budget, statistical analyses and figures) are archived on Zenodo (version 1.1, <https://doi.org/10.5281/zenodo.23505759>), together with the required third-party functions and their licences, the MHW event catalogues of each sub-region and the derived products needed to reproduce the figures. The analyses were performed with MATLAB R2017a. The function `mean_and_trend.m` of the `m_mhw` toolbox was not used. Trends are estimated with three functions from MATLAB Central File Exchange: the Mann–Kendall test with `Mann_Kendall1.m` (S. Fatichi); the Sen slope of the regional series (Table 2, Fig. 6) with `ktaub.m` (J. Burkey); and the slopes of the grid-cell trend maps (Figs. 1b, 4 and 5) and the trend lines of the figures with `TheilSen.m` (Z. Danziger), which implements the same estimator (median of the pairwise slopes). The “Code and data availability” section has been completed accordingly.

2. l.150–170, 209–239, and Figures 7–9: Make the event table and composite construction reproducible.

How were the regional events identified? Detecting events in a spatially averaged SST series is not equivalent to detecting them at individual grid cells (or contiguous regions of grid cells) and then averaging their properties. Table 1 contains 92, 102, and 89 regional events, which sum correctly to 283; the seasonal totals also agree with the Figure 8 caption. However, the methods do not explain precisely how they were constructed. Please specify the spatial averaging and weighting, the event-selection rule, and whether you count simultaneous events in different regions separately. For the spatial chl-a composites, state whether each grid cell uses its own event dates or a regional pool.

Response. We thank the referee. The regional MHWs were detected from the SST averaged over each box: for each sub-region, the daily SST series is the arithmetic mean of the OISST continental-shelf cells (0 to –200 m), and the detection (90th-percentile threshold, minimum duration of 5 days; Hobday et al., 2016) is applied once to this series. Events are therefore not detected cell by cell and then aggregated. No area weighting is applied; within each box, the cell area varies by less than 2 % with latitude, which makes this weighting negligible. Each sub-region is treated independently: an event occurring simultaneously in two sub-regions is counted once in each.

The redefinition of the Cap Blanc boundaries (20.8–22°N instead of 20–22°N; comment 5) slightly changes the number of events: Table 1 now contains 83, 104 and 90 events at Cap Blanc, Grande Côte and Petite Côte (277 in total), against 92, 102 and 89 previously. The conclusions remain unchanged.

For the Chl-a composite maps (Fig. 10), detection is, in contrast, performed cell by cell: each cell uses its own event dates. The temporal Chl-a composites (Fig. 10a1–c1 and Table 3) use the regional events. These rules are now specified in the Methods.

The baseline description is inconsistent. Section 2.3 specifies 1982–2011 for MHW detection, whereas l.237–238 say that the full 1998–2024 period was used to calculate the seasonal chl-a climatology and detect events for the biological analysis. Was the original dataset restricted to the chl-a era, or were MHWs redetected against a different SST baseline? Please distinguish the chl-a climatology more clearly from the SST detection climatology. Unless there is a specific reason to change event definitions, use the same SST baseline and compare the physical and biological composites over the same event subset. Otherwise, differences between their samples could be mistaken for physical–biological relationships.

Response. We thank the referee and have clarified this point. Two sets of events are used, each for a distinct purpose. The MHW climatology and trends (Sects. 3.1–3.2) rely on detection over 1982–2024 with the 1982–2011 baseline. In the original manuscript, the physical composites were computed over the whole 1982–2024 period. The mechanism analyses (physical composites, heat budget and Chl-a composites) are now all restricted to 1998–2024, the period common to satellite Chl-a and GLORYS12V1. For these analyses, MHWs were detected over 1998–2024 with a 1998–2024 baseline, so that the SST and Chl-a anomalies of a given composite are computed relative to the same reference period. The physical and biological composites are therefore based on exactly the same events (61, 53 and 50 at Cap Blanc, Grande Côte and Petite Côte; Fig. 7 and Table 3). The baseline sensitivity test (Table A5) shows that the baseline mainly affects the number of events and the cumulative days, and only slightly the intensity. Finally, the composites computed over the 1982–2024 events show the same sequence and the same regional and seasonal contrasts (Fig. A12): restricting the analysis to 1998–2024 does not change the conclusions on the mechanisms.

Please clarify the filtering at l.224–225. Does the 30-day low-pass filter act on the climatological seasonal cycle, the anomaly time series, or both? Was SST filtered before detection? Report the filter type, window, phase treatment, and how you handled record boundaries.

Response. We thank the referee. No filter is applied to SST before detection, nor to the anomaly series: the anomalies are the raw daily values minus the climatology of the corresponding calendar

day. Only the daily climatology and the 90th-percentile threshold are smoothed, following the method of Hobday et al. (2016) implemented in the `m_mhw` toolbox. For each calendar day, the mean (or the 90th percentile) is first computed over all values of the reference period falling within an 11-day window centred on that day. The resulting annual cycle is then smoothed by a centred 31-day moving average, which introduces no phase shift. To avoid edge effects, this smoothing is applied to the annual cycle repeated three times, which ensures continuity between December and January; 29 February is the mean of the neighbouring days. At the ends of the reference period, only the values available within the 11-day window are used. The same procedure is applied to the other variables (wind, fluxes, upwelling indices, Chl-a) to compute their anomalies. The mention of a “30-day low-pass filter” in the original manuscript was imprecise and has been replaced by this description (Sect. 2.5.2).

The abrupt 2–3-day warming described at l.378–379 and the short fluctuations in Figures 7–9 need to be reconciled with this statement. If you applied a centred filter to anomalies, it can spread changes into the period before onset and affect inferred biological lead times. An unsmoothed or minimally smoothed sensitivity comparison would resolve this.

Response. Since no filter is applied to the anomalies, the composites of Figs. 7, 8 and 10 are already unsmoothed: they cannot spread changes into the period preceding onset, and the inferred biological lead times are not affected. The rapid 2–3-day warming around onset is explained by the construction of the composite: day 0 is, for each event, the first day on which SST exceeds the threshold, so that aligning the events on this day concentrates the threshold crossing around day 0. This maximum SST anomaly corresponds to the maximum intensity of the events.

The composite curves and maps also need uncertainty estimates. Show the number of contributing events or valid observations at each lag, and explain the handling of overlapping windows, nearby events, events longer than 30 days, and incomplete windows. Use an uncertainty procedure that preserves dependence within events and accounts for temporal clustering; resampling individual daily values would not do this. Compare with seasonally matched non-event windows, or another justified reference, to establish how unusual the composite anomalies are. Where long-term changes could explain persistent offsets, test sensitivity to those changes while retaining the fixed-baseline analysis for historical MHW trends. Please also define the preconditioning, onset, and offset intervals used in Figure A3. A window centred on onset does not align with event termination, so its post-onset mean is not automatically a common decay trajectory.

Response. We thank the referee. All events are used in the composites. Days belonging to another MHW are excluded day by day (solid lines), and the composites including all days are shown for comparison (dashed lines) (Figs. 7, 8 and A11). No ± 30 -day window extends beyond the limits of the record.

We tested the robustness of the composites in a dedicated sensitivity analysis, on the same events as Figs. 7–8 (61, 53 and 50 at Cap Blanc, Grande Côte and Petite Côte). For each lag, it gives the number of contributing events and a 95 % confidence interval obtained by a cluster bootstrap over events (2000 draws; events whose windows overlap are resampled together, i.e. 30, 27 and 22 clusters). It also compares the composites with a null reference of 1000 composites built on seasonally matched non-MHW windows (± 15 calendar days). The warming, the wind relaxation and the decrease in EPV and CUI around onset lie outside this null envelope in all three sub-regions, over the full year and during the cooling period (Figs. R6–R8). During the warming period, this is also the case at Cap Blanc and Grande Côte; at Petite Côte, where the forcing is weaker, the wind relaxation and the decrease in EPV remain within the null envelope, and only the warming and the decrease in CUI are significant. This test is now described in the manuscript (Sect. 2.5.2), with reference to established random-date approaches in composite analysis (Grotjahn et al., 2016; Gröger et al., 2024). Events longer than 30 days are few (4.9, 11.3 and 14.0 % of events); the composites of events lasting 5 to 30 days and those of all events are practically identical. We therefore kept all events.

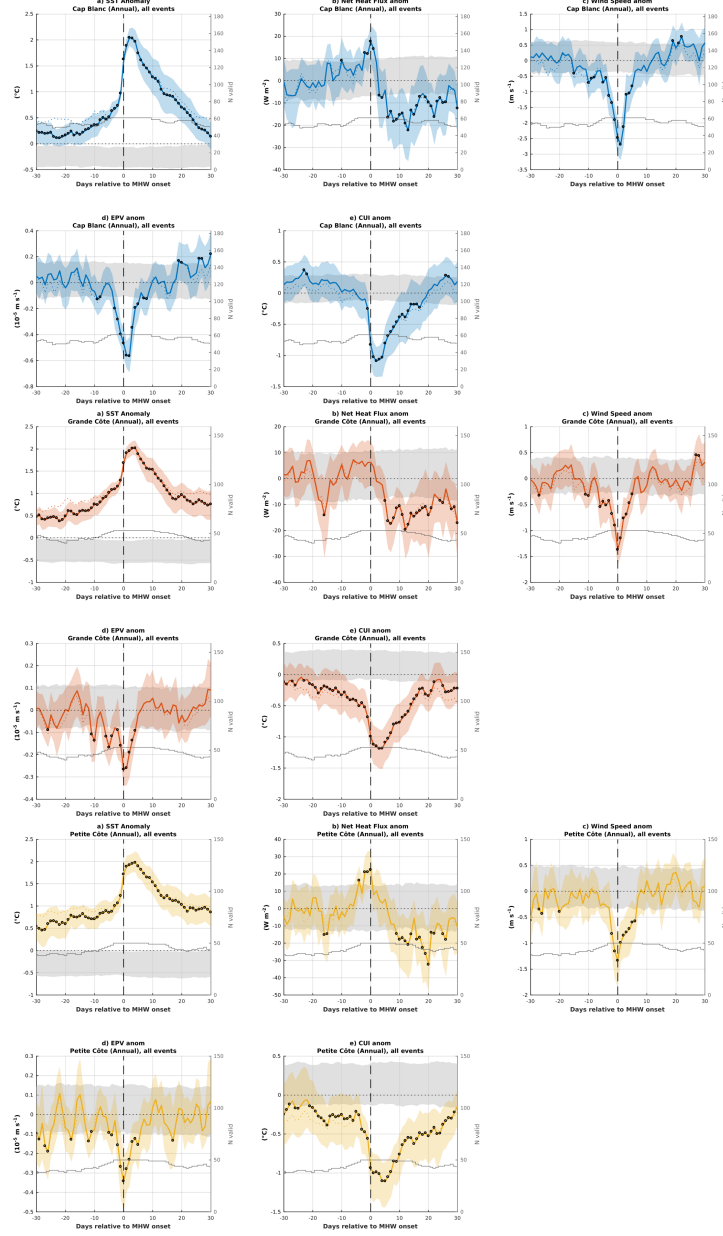


Figure R6: Composite anomalies around MHW onset (1998–2024), full year, at Cap Blanc (top), Grande Côte (middle) and Petite Côte (bottom): (a) SST, (b) net heat flux, (c) wind speed, (d) EPV and (e) CUI. Solid line: composite excluding days belonging to another MHW, with its 95 % confidence interval (event-cluster bootstrap, coloured shading); dotted line: composite including all days; grey shading: null envelope (2.5–97.5 percentiles of 1000 composites built on season-matched non-MHW windows); grey staircase (right axis): number of contributing events.

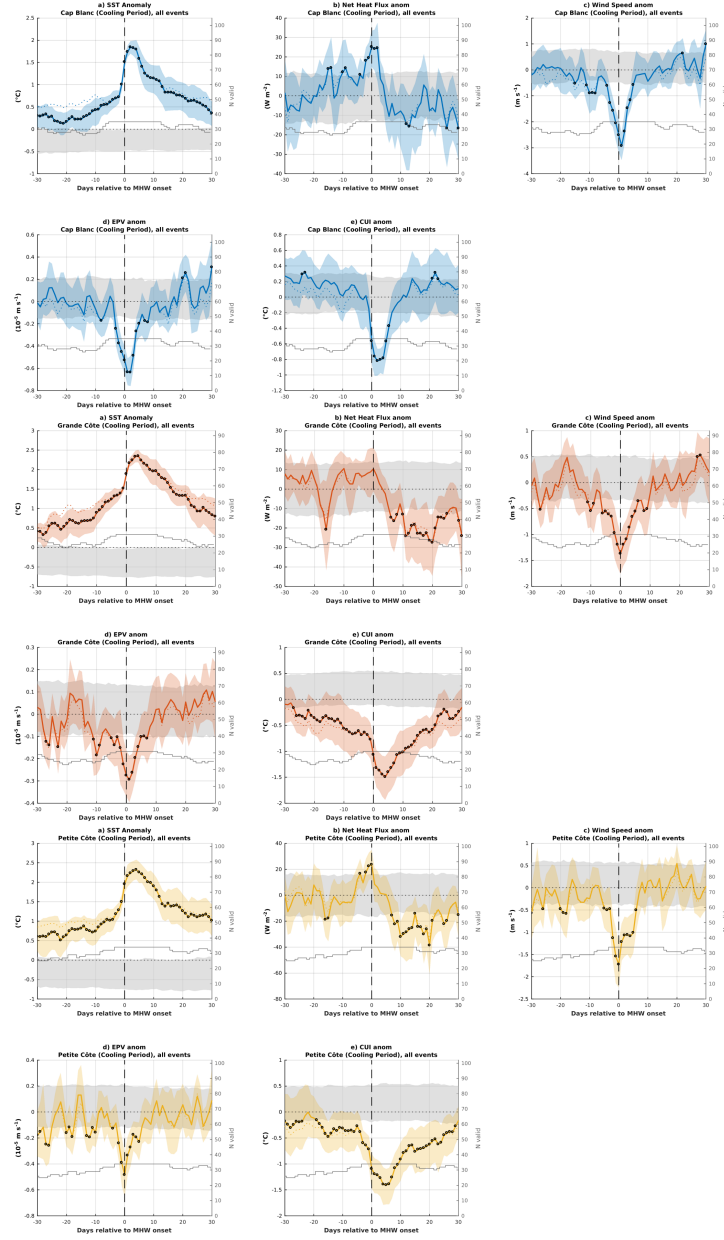


Figure R7: Composite anomalies around MHW onset (1998–2024), cooling period (November–May), at Cap Blanc (top), Grande Côte (middle) and Petite Côte (bottom): (a) SST, (b) net heat flux, (c) wind speed, (d) EPV and (e) CUI. Solid line: composite excluding days belonging to another MHW, with its 95 % confidence interval (event-cluster bootstrap, coloured shading); dotted line: composite including all days; grey shading: null envelope (2.5–97.5 percentiles of 1000 composites built on season-matched non-MHW windows); grey staircase (right axis): number of contributing events.

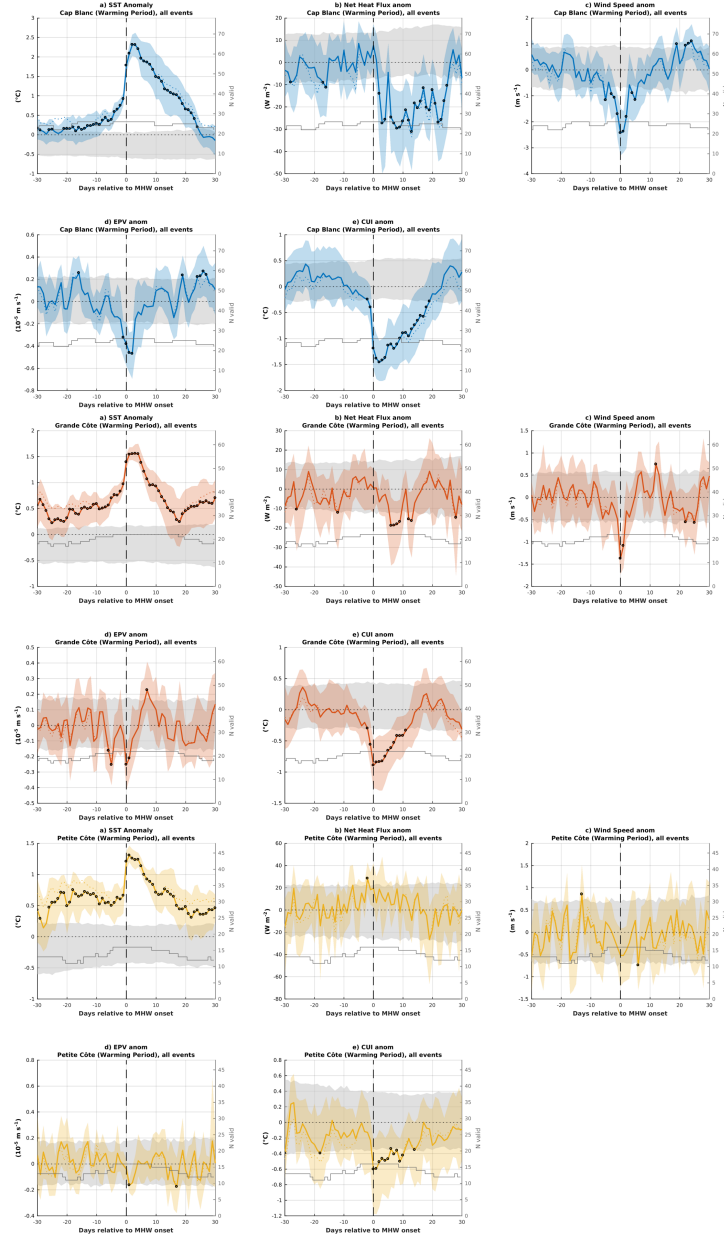


Figure R8: Composite anomalies around MHW onset (1998–2024), warming period (June–October), at Cap Blanc (top), Grande Côte (middle) and Petite Côte (bottom): (a) SST, (b) net heat flux, (c) wind speed, (d) EPV and (e) CUI. Solid line: composite excluding days belonging to another MHW, with its 95 % confidence interval (event-cluster bootstrap, coloured shading); dotted line: composite including all days; grey shading: null envelope (2.5–97.5 percentiles of 1000 composites built on season-matched non-MHW windows); grey staircase (right axis): number of contributing events.

In the paper, uncertainty is shown in the phase-averaged composites (Figs. A9–A10), with error bars of ± 1 standard error across events. The phases are defined from the course of each individual event: preconditioning (days -3 to -1), onset (from the start to the peak) and decline (from the day after the peak to the end). The decline is thus aligned with the end of each event, and not with a fixed window centred on onset. We nevertheless keep the day-by-day evolutions in the main text (Figs. 7–8), because they show structures that the phase average masks, for example the positive CUI before event onset.

3. 1.133–148, 235–239, and 449–505; Table 3: Reveal the chl-a result before assigning nutrient, light, and temperature mechanisms.

The Cap Blanc seasonal contrast merits attention, and Table 3 usefully shows that individual events differ. Please develop this evidence. Give uncertainty intervals for the event-level responses and positive-response proportions, test the seasonal contrast with appropriate allowance for temporal dependence, and show whether the mean is sensitive to a few large blooms. The 22/34 positive cooling-period responses at Cap Blanc and 6/26 warming-period responses are more informative than a claim based only on the largest composite anomaly. The southern response is predominantly negative, but not always: Table 3 reports positive responses in 14% of Grande Côte events and 30% of Petite Côte events across the year. The abstract’s description of a systematic decrease needs qualification.

Response. We thank the referee for this suggestion. By harmonising the sub-region boundaries (comment 5), the percentages of positive responses changed: at Cap Blanc, 26 of 35 events are positive during the cold period (74 %, 95 % CI: 58–86 %) instead of 22 of 34, against 6 of 26 during the warm period (23 %, CI: 11–42 %). Table 3 now gives, for each sub-region and season, the proportion of positive responses with its 95 % confidence interval (Wilson). The seasonal contrast at Cap Blanc was tested with a cluster bootstrap over events (5000 draws; events separated by less than 30 days are resampled together), which accounts for temporal dependence: it is significant, with +51 percentage points of positive responses (CI: +25 to +73; $p = 0.001$) and +2.3 mg m⁻³ in mean anomaly (CI: +0.9 to +3.8; $p = 0.001$). The mean cold-period anomaly (+1.29 mg m⁻³, CI: +0.49 to +2.51) is partly driven by a few strong blooms, but the median (+0.61 mg m⁻³) and the mean without the two strongest (+0.71 mg m⁻³) remain positive. In the south, the response is predominantly negative, but not systematically: 19 % (Grande Côte) and 32 % (Petite Côte) of events are positive over the year, and up to 44 % at Petite Côte during the warm period, when the mean anomaly is close to zero. The abstract now states “predominantly negative (68–81 % of events)” instead of “systematic decrease”.

The chl-a product must be identified precisely, including its product and dataset identifiers, processing version, and whether daily values are observed Level 3 fields or temporally and spatially filled Level 4 fields. This difference is important for event timing. The cited Garnesson et al. (2019) product paper describes both daily and daily-filled products, with the latter incorporating spatial and temporal interpolation. Please report quality flags, cloud-related missingness, minimum event coverage, and the number of retained observations. Explain the averaging of this skewed variable and add relative or log-scale anomalies to the absolute mg m⁻³ differences. Larger cooling-period losses in absolute units may partly reflect a larger seasonal chl-a baseline.

Response. We thank the referee. The original manuscript did not specify the product level. The product used throughout the study is the gap-free multi-sensor Level-4 GlobColour product of the Copernicus Marine Service (OCEANCOLOUR_GLO_BGC_L4_MY_009_104, dataset cmems_obs-oc_glo_bgc-plankton version 202311), in which gaps due to cloud cover are filled by spatio-temporal interpolation (Garnesson et al., 2019). A value is therefore available every day for all sub-regions and all events. The product is now identified in Sect. 2.2 and in the “Code and data availability” section. Chl-a anomalies are computed with the same method as those of SST and the other variables: Chl-a is averaged over the shelf cells of each sub-region (arithmetic mean), and the anomaly is then computed relative to the daily climatology, obtained with an 11-day window centred on each calendar

day and then smoothed by a 31-day moving average (comment 2.3).

Surface chl-a is a useful proxy, but it does not directly measure phytoplankton carbon, primary production, nutrient limitation, or growth rate. Nutrients, light, mixed-layer depth, grazing, and phytoplankton physiology are not measured in this study. Changes in pigment content, vertical redistribution, transport, and losses could contribute to the observed signal. So, the detailed N–L–T explanation at l.465–497 remains a proposed interpretation. Please define this framework before using it and reduce the claims that its separate terms have been assessed/identified. In particular, the study cannot establish enhanced photosynthetic efficiency or a measured reduction in primary production from chl-a alone. The negative southern chl-a anomalies already present at day –30 deserve explicit consideration. They may indicate shared environmental preconditioning rather than a response caused by the subsequent threshold-defined MHW. This is another reason to examine matched reference windows and the filtering. The warming-period observations in Table 3 remain valid observations even where the proposed upwelling explanation is inapplicable. Please discuss that limitation instead of labelling the responses themselves as not physically interpretable. Also, keep fisheries and spawning implications as motivation and possible consequences, since the analysis contains no direct measurements of those outcomes.

Response. We thank the referee for these two comments, which we answer together, because the section on the Chl-a response (Sect. 3.5) has been entirely rewritten. We agree that surface Chl-a measures neither phytoplankton carbon, nor primary production, nor nutrient limitation, nor growth rate. The nutrient–light–temperature explanation has been reformulated. Only the hypothesis of a reduced nutrient supply by upwelling in the south is retained, supported by previous studies (Noh et al., 2022; Ma et al., 2025) and explicitly presented as indirect, since neither nutrient data nor a separate estimate of vertical advection is available. The role of light through mixed-layer shoaling is not retained, because the shoaling is the same for positive and negative responses at Cap Blanc. Statements about photosynthetic efficiency and primary production have been removed. The interpretation involving a reduced supply of subsurface water in the south is explicitly presented as indirect, since neither nutrient data nor a separate estimate of vertical advection is available.

The comment on the anomalies present before onset changed one of our conclusions. Comparing events with positive and negative responses shows that, during the cold period, the Chl-a anomaly already has the sign of the response during preconditioning in all three sub-regions, whereas the physical forcing, the heat-budget terms and event duration do not differ between the two groups (Table A7). We now conclude that the response largely reflects the state of the ecosystem before the event, rather than a response caused by the MHW; this conclusion is stated in the abstract and the conclusion. Warm-period responses are discussed as valid observations, including where the upwelling explanation does not apply. Finally, fisheries and spawning are now mentioned only as motivation in the Introduction, and the limitations paragraph states that surface Chl-a captures neither the subsurface maximum, nor nutrients, nor primary production, and that the associations presented do not establish ecological or fisheries impacts.

4. 1.209–215, 288–312, 328–369, and 517–525; Tables 1–2: Reassess the seasonal and trend claims against the actual metrics.

Cooling and warming periods contain seven and five months, respectively. Comparing their raw event counts or cumulative days does not demonstrate a higher occurrence rate in the longer season. Table 1 is especially useful. . . Grande Côte has 47 cooling-period events and 55 warming-period events, despite the longer cooling period. Its cooling-period events last longer on average, but they are not more numerous. At Cap Blanc, mean duration is almost identical between periods. Please distinguish event frequency, total MHW days, and event duration throughout. Keep the seasonal totals if they represent the intended measure of exposure, but also provide an occurrence rate or proportion of eligible days when comparing seasons. Explain how events crossing a season or year boundary contribute to each metric, particularly because the current assignment uses the date of maximum intensity.

Response. We thank the referee. We agree that raw numbers of events and days do not allow two seasons of seven and five months to be compared. Table 1 now gives, for each season, the number of events, the total number of MHW days, the mean duration and the MHW-day fraction (MHW days divided by the number of days of the season over 1982–2024). The text now distinguishes these metrics and gives the occurrence rate (events per month of the season) (l. 428–431). After normalisation, the seasonal contrast remains clear only at Petite Côte, where the cold period combines more events (0.20 against 0.14 per month) and longer events (16.8 against 11.6 days), giving an MHW-day fraction of 11.0 % against 5.3 %. At Grande Côte, as noted by the referee, events are more frequent during the warm period (0.26 against 0.16 per month) but longer during the cold period (19.1 against 13.3 days), so that the fractions are close (10.1 and 11.4 %). At Cap Blanc, frequency, duration and fraction are similar between the two seasons.

Each event is assigned to a single season and a single year, those of the date of its maximum intensity. Its count, all its days, its duration and its intensity are counted in that season and that year, even when part of the event falls in the neighbouring season or year. There is therefore no double counting, and the MHW-day fraction is an approximate measure of the proportion of days of the season affected. This is now specified in the Methods and in the caption of Table 1 (l. 297–300). An assignment by calendar year changes neither the sign nor the significance of the trends.

The statement at l.16 that Cap Blanc is stable across all indicators conflicts with its significant annual MHW-day trend of $+4.35$ days decade⁻¹ in Table 2 and Figure 6. A narrower near-coast area in Figure 4 could behave differently from the regional average, but that distinction must be explicit. Moreover, a non-significant trend is not evidence of no change. The smaller Cap Blanc trend may support relative moderation of thermal exposure, but it does not show (or even hint at) complete stability or protection of an ecosystem.

The claim that Grande Côte trends are strongest particularly during the cooling period also needs precision. Table 2 gives MHW-day slopes of $+6.75$ and $+6.00$ days decade⁻¹ for cooling and warming periods, while duration slopes are $+2.35$ and $+2.64$ days decade⁻¹, respectively. These do not support a general statement that both trends are much stronger in the cooling period. Report uncertainty and test contrasts directly where differences among regions or seasons are central to the argument. Significance in one series and non-significance in another do not demonstrate a significant difference between them. Separately estimated Sen slopes need not add across seasons, so non-additivity alone would not establish an error.

Please state the annual or seasonal observations used for the Mann–Kendall tests and Sen slopes, including how years without events are handled. Zero event counts are meaningful, but a year without events has no event duration or intensity to average. Address serial dependence and explain how you treated the many grid-cell tests. Confidence intervals for regional slopes, along with an appropriate assessment of spatial significance, would make the main comparisons more useful than significance stars alone. The exceptional recent years also require a sensitivity check on the inference about long-term change.

Lastly, define how you aggregate maximum intensity. Is it the mean of individual event maxima, the largest value in each year, or a maximum over the full record? These are different quantities, and the distinction is important when comparing Table 1 with Figures 2, 3, and 6. Figure A2 also requires correction or explanation... its month-specific MHW-day values reach hundreds, although the caption describes days per year. State the accumulation period and denominator explicitly.

Response. We thank the referee for these comments, which we answer together.

Trend statements. We agree that a non-significant trend does not indicate the absence of change. With the harmonised Cap Blanc boundaries (comment 5), the annual trend in MHW days there is $+4.8$ days per decade (95 % CI: 0.0 to $+10.6$; $p = 0.07$). All mentions of “stability” have been removed: we now write that the trends at Cap Blanc are weaker and non-significant, which suggests at most a relative moderation of thermal exposure, without stability or protection of the ecosystem. The narrow coastal zone (21–22°N, Fig. 6) is distinguished from the regional mean. At Grande Côte, the trends in MHW days are $+4.4$ (cold period) and $+5.7$ (warm period) days per decade, and a direct test on the paired annual series CP – WP shows no difference ($p = 0.24$; duration: $p = 0.93$). The text therefore no longer states that trends there are stronger during the

cold period.

Statistical method. The Mann–Kendall tests and Sen slopes are applied to annual series (one value per year and per season, 1982–2024). Years without events count as zero MHW days and zero events, and are excluded from the duration and intensity series; the number of years used is given in Table 2. Table 2 now gives the 95 % CI of each Sen slope. The Mann–Kendall test corrects for ties, which are numerous in the seasonal series, and serial dependence was accounted for with the modified test of Hamed and Rao (1998). Lag-1 autocorrelation is weak, and no conclusion changes. The zero slopes of some seasonal series reflect the large number of years without events, as stated in the caption. For the maps, significant points are now identified after correcting for multiple testing with the Benjamini and Hochberg method (false discovery rate of 5 %). The trends in MHW days and duration remain significant over most of the domain, but no point remains significant for maximum intensity; the local increase in intensity near the Cap Blanc front has therefore been removed. Finally, the sensitivity to exceptional years (Tukey’s rule) is given in the appendix (Table A6): the annual trends in MHW days remain significant at Grande Côte and Petite Côte, with an amplitude reduced by about 30 %.

Maximum intensity and Fig. A2 (now Fig. A2). Maximum intensity is the mean of the maximum intensities of individual events: per year in Table 2 and Fig. 6, and over 1982–2024 in Table 1 and Figs. 2 and 3. The captions now state this. Fig. A2a shows the cumulative MHW days over the whole 1982–2024 period, month by month, and not days per year; the caption has been corrected.

More specific comments

l.31–34 and references at l.660–662: Please check both the numerical claim about increasing MHW frequency and its citation. The reference list gives Eric Oliver et al.’s eastern Tasmania paper, whereas the global trend discussion appears to require Oliver et al. (2018), Longer and more frequent marine heatwaves over the past century. Confirm that the stated percentage, metric, and time interval match the source. Also verify the claim that EBUS contain 20% of global marine biomass on 1% of the ocean surface. Biomass, primary production, and fish catches are different quantities

Response. We thank the referee. Both points have been corrected. The citation referred by mistake to Oliver et al. (2018, Prog. Oceanogr.), devoted to eastern Tasmania. It now refers to Oliver et al. (2018, Nat. Commun.), with the statistics of that paper: between 1925 and 2016, the global mean MHW frequency (annual number of events) increased by 34 %, and the annual number of MHW days by 54 %. For the EBUS, we had wrongly written “biomass”: the cited sources (Chavez and Messié, 2009; Messié and Chavez, 2015) indicate that they provide about 20 % of global fish catches while covering less than 1 % of the ocean surface. The sentence has been corrected accordingly.

l.55–67 and 84–96: Define the new contribution more precisely relative to the regional work already cited. Imbol Koungue et al. (2025) examined low primary-productivity events and Dakar Niños, including local wind forcing and remote coastal-trapped waves. Zhan et al. (2024) assessed phytoplankton changes in EBUS, with their Canary domain extending from 20 to 40° N. Your study extends substantially farther south and resolves contrasting seasonal regimes, which is a plausible contribution. Explain that contribution without implying the broader physical-biological question has not been studied. Neither cited study is missing from the bibliography, but the manuscript lacks more direct/precise engagement with their findings and scope.

Response. We thank the referee. The Introduction paragraph has been rewritten to present the results and scope of these two studies more directly. Imbol Koungue et al. (2025) showed that low primary-productivity episodes in the SMUS are associated with Dakar Niños, in connection with local wind forcing and remotely forced coastal-trapped waves; their analysis concerns interannual anomalies and not daily threshold-defined MHWs. Zhan et al. (2024) showed that, in EBUS,

MHWs are generally accompanied by a decrease in phytoplankton biomass and a shift towards smaller phytoplankton, and that they are mainly driven by oceanic processes; their Canary domain extends from 20 to 40°N and therefore excludes most of the SMUS. We now present our contribution as an extension of this work to the tropical part of the Canary system, where upwelling is maximal in winter and changes from a permanent regime in the north to a seasonal regime in the south, and as an examination of how the Chl-a response depends on season and upwelling regime. We no longer state that the general physical–biological question has not been studied.

l.126–132: Cite the version-specific OISST paper, Huang et al., Improvements of the Daily Optimum Interpolation Sea Surface Temperature (DOISST) Version 2.1, alongside any historical product reference. The description of satellite inputs should also reflect the actual period used. NOAA’s product documentation records changes in satellite inputs, including the use of AVHRR and VIIRS in later production. An AVHRR-only description is incomplete for the full record.

Response. We thank the referee. Huang et al. (2021) is now cited as the reference for version 2.1, with Reynolds et al. (2007) and Banzon et al. (2016) for the earlier versions of the product. The description of the satellite data now covers the whole period: the product relies on AVHRR for most of the archive, with VIIRS added to the input data in October 2021, and on in situ measurements (ships, buoys and Argo floats) for bias correction, in accordance with the NOAA documentation, now cited.

l.153–162: Please report the smoothing of the daily climatology and threshold, in addition to the 11-day sampling window. The linked detection function includes a default 31-day smoothing window; identify the settings actually used. The claim that 1982–2011 captures a complete AMO cycle is not supported, as it spans parts of both a negative and a positive phase. The cited Knight et al. (2005) discusses an observed period of approximately 65 years. A fixed 30-year baseline is defensible, but describe what it measures and test sensitivity to the baseline rather than calling a later baseline intrinsically biased or the earlier anomalies the true amplitude.

Response. We thank the referee. The parameters actually used are now stated: the default settings of the toolbox of Zhao and Marin (2019), i.e. an 11-day window centred on each calendar day, followed by a 31-day moving-average smoothing of the climatology and threshold. The argument of a complete AMO cycle and the statement that a more recent baseline would be biased have been removed. The 1982–2011 baseline is kept as a fixed, WMO-compliant 30-year baseline; the text now states that, with a fixed baseline, MHWs are defined relative to the 1982–2011 climate, so that their increase includes the effect of long-term warming. The sensitivity to the baseline was tested with the 1991–2020 period (Table A5). The more recent baseline reduces the number of events by 6.0 to 17.3 % and the cumulative days by 11.6 to 27.3 % depending on the sub-region, whereas the mean maximum intensity changes little (−1.7 to +2.8 %) (l. 196–201).

l.253–280: The coldness of upwelled water alone does not explain fewer percentile-defined MHWs, because the threshold is local and seasonally varying. Discuss warming relative to the local baseline, variability, and persistence. The explanations involving heat advection, frontal gradients, and stratification also need to be separated: a horizontal SST gradient does not directly measure vertical stratification or advective heat convergence.

Response. We thank the referee. We agree: since the threshold is local and seasonal, the coldness of upwelled waters alone cannot explain the lower number of MHW days. The text now relates MHW characteristics to the properties of SST anomalies relative to the local baseline, as established by previous studies (Oliver et al., 2018; Oliver, 2019): the number of MHW days to local warming, duration to the persistence of anomalies and intensity to their variability. Explanations based on the “thermal properties of upwelled waters” have been removed. For intensity, we state that the maxima coincide with thermal fronts, but we specify that a horizontal SST gradient measures neither heat advection nor vertical stratification. The sentence attributing intensity to stratification has been removed, and the contribution of advection is quantified at the sub-region scale by the

heat budget (Sect. 3.4).

l.362–367: An annual total approaching 180 MHW days does not establish that one event lasted 180 days. Describe 2023 as an exceptional year unless an individual event duration is shown. AMO and ENSO contributions remain hypotheses here because the authors have not analysed their relationships with the event series. Consider remote forcing when discussing possible drivers, rather than assigning local wind relaxation as the trigger for every event.

Response. We thank the referee. The year 2023 is now described as an exceptional year, with more than 180 cumulative MHW days distributed over several events, and not as a single event (l. 530–532). The attribution to the AMO and ENSO, which we had not analysed, has been removed. The composites show that, on average, MHW onset is associated with a relaxation of the trade winds.

l.406–413 and Figure 7a; Figure A3: Please check the quoted Cap Blanc recovery value against the curve. Figure 7a appears to end near +0.6 °C at day +30, rather than +0.2 °C. Figure A3 also shows a Cap Blanc longwave anomaly near +8 W m⁻² at onset, which is not obviously negligible alongside the reported net-flux anomalies. Define the averaging intervals and match these descriptions with the plotted values.

Response. We thank the referee. The composites were recomputed over 1998–2024, excluding the days belonging to another MHW (Sect. 3.3.1). With this masking, the SST anomaly at Cap Blanc at day +30 is about +0.15 °C (solid curve of Fig. 7a). The value close to +0.6 °C noted by the referee on the original figure came from the contribution of subsequent events; it remains visible on the dashed curve, which includes all days (about +0.45 °C). All values quoted in the text have been checked against the new figure. The former Fig. A3 has been replaced by the decomposition of the air–sea fluxes of the heat budget (Fig. A4), in which the averaging intervals are explicitly defined: preconditioning (days –3 to –1), onset (from the start to the peak) and decline (from the day after the peak to the end). The longwave flux is shown there, and the statement that it is negligible has been removed.

l.669–670: The Schlegel, Oliver, and Chen (2021) reference does not match the identifiable paper by those authors. Please verify the intended source. Their published article is Drivers of Marine Heatwaves in the Northwest Atlantic: The Role of Air–Sea Interaction During Onset and Decline, Frontiers in Marine Science, 8, 627970. Correct the bibliography and check whether each associated claim is supported by that paper.

Response. We thank the referee. The reference has been corrected to Schlegel, Oliver and Chen (2021), Drivers of marine heatwaves in the Northwest Atlantic: The role of air–sea interaction during onset and decline, Front. Mar. Sci., 8, 627970, doi:10.3389/fmars.2021.627970. We checked that each statement is supported by this paper. It is now cited in only two places: in the Introduction, for the role of air–sea heat exchange in MHWs (the paper shows that the latent heat flux is the most frequent driver of onset, and that oceanic processes dominate decline), and in Sect. 2.2, as an example of an MHW study based on OISST v2.1, the product it uses.

l.508–552: Shorten the conclusion to the established spatial pattern, the qualified seasonal and trend comparisons, and the chl-a associations. Add a concise limitations paragraph in the discussion. It should cover the surface-only observations, resolution, incomplete mechanism attribution, event/composite uncertainty, and shorter chl-a record. Thermal exposure does not on its own establish ecological vulnerability or fisheries impacts, so qualify those terms.

Response. We thank the referee. The conclusion has been reduced to the spatial structure of MHWs, the qualified seasonal and trend results, the heat budget and the associations with Chl-a. A concise limitations paragraph has been added to the Conclusion (l. 797–804). It covers the surface-only observations, the data resolution, the incomplete attribution of mechanisms (the residual term of the budget groups vertical processes, assimilation increments and unresolved processes), the

uncertainty related to the number of events and to the composites, and the shorter Chl-a period. It states that thermal exposure and the associations presented are not sufficient to establish ecological vulnerability or fisheries impacts, and these terms have been qualified throughout the text.

Technical corrections

- *l.4-5: Be upfront re the identity of the data products used here.*
- *l.10 and abstract: Define CP at first use, and distinguish the SST/physical record from the shorter chl-a record. If the record contains all of 1982–2024, it contains 43 calendar years, not 42.*
- *l.100, 118, and 122: The study-area, SST-threshold, and SST-trend references to Figure A1 appear to require Figure 1. Check all figure references.*
- *l.89–90, 93–95, and 348–349: Rewrite the incomplete or awkward sentences, including “Then, are examined”, “allows to disentangle”, and “spatially averages in each three sub-regions”.*
- *Section 3.2.1 heading: Remove “inof”. l.365–367: Correct “begining”, “21th”, and “inprint”, and repair the sentence punctuation.*
- *l.396: Correct “anti-symetrical”.*
- *Figure 3: The warming-period panel labels repeat a1, b1, and c1; change them to a2, b2, and c2.*
- *Figure 8 caption: Cooling and warming periods occupy the upper and lower groups of panels, not left and right panels.*
- *Table 2 and Figure A5a3: Reconcile the Petite Côte warming-period MHW-day slope: +1.34 in the table and abstract, but +1.38 in the figure.*
- *Figure A5 caption: The region-specific bars do not use the blue/orange/yellow regional colour scheme described in the caption.*
- *Figure A1b2: Correct its internal panel label, which repeats a2.*
- *Figures 2c and A6b: Supply units for the SST-gradient contours.*
- *Figure 9: Add a reference magnitude for wind vectors and use a clearly identified zero-centred scale for chl-a anomalies.*
- *Figure A3: Number panels consistently and define the abbreviated phase labels.*
- *Table 3, p.26: Repair the caption, whose beginning is clipped in the supplied PDF.*
- *l.563–565: Use the toolbox’s name, `m_mhw`, consistently and replace the incomplete `/blob/master/` link with a working repository or archived-version link.*
- *Throughout: Standardise the study-region name, Grande Côte/Petite Côte spelling, chl-a notation, and regional bounds. Distinguish raw indices from their anomalies in labels and prose. Correct the EPV units only after checking the calculations described above.*

Response. We thank the referee for these corrections, all of which have been taken into account.

- l. 4–5, data products: the abstract now names OISST v2.1, ERA5, GLORYS12V1 and the satellite Chl-a product.
- l. 10, CP and record length: CP and WP are defined at first use. The SST and physical-variable record (1982–2024, 43 years) is distinguished from the shorter Chl-a record (1998–2024).
- l. 100, 118 and 122, figure references: they now refer to Fig. 1, and all figure references have been checked.
- l. 89–90, 93–95 and 348–349, awkward sentences: rewritten.
- Heading of Sect. 3.2.1; l. 365–367; l. 396: “inof”, “begining”, “21th”, “inprint” and “anti-symetrical” have been corrected, as well as the punctuation.

- Fig. 3: the warm-period panels are now labelled a2, b2 and c2.
- Caption of Fig. 8: it now refers to the upper (cold period) and lower (warm period) panels.
- Table 2 and Fig. A5a3 (now Fig. A6): all slopes were recomputed with the same script, after the harmonisation of the Cap Blanc boundaries; the table, the text and the figures now give the same values.
- Caption of Fig. A5 (now Figs. A5–A6): the bar colours now match the regional colour scheme described in the caption.
- Fig. A1b2: the panel label has been corrected.
- Figs. 2c and A6b (now Fig. A7b): the unit of the SST-gradient contours is given ($^{\circ}\text{C} (100 \text{ km})^{-1}$).
- Fig. 9 (now Fig. 10): a reference arrow for the wind and a symmetric colour scale centred on zero for the Chl-a anomalies have been added.
- Fig. A3: it has been replaced by the phase-based heat-budget figures (Figs. A3 and A4), with consistent panel numbering and the definition of the phases in the caption.
- Caption of Table 3: repaired.
- l. 563–565, toolbox: the name `m_mhw` is used consistently, with a working link to the repository (https://github.com/ZijieZhaoMMHW/m_mhw1.0).
- Throughout the text: the name of the study region (Senegalo–Mauritanian Upwelling System), the spelling of Grande Côte and Petite Côte, the Chl-a notation and the sub-region boundaries have been harmonised. Raw indices and their anomalies are distinguished in labels and text. The EPV units have been corrected after checking the calculation (comment 5.4).