

Reviewer 1 Comments

General Comments:

This study investigates regional differences in Chl-a responses to MHWs in the South China Sea, focusing on two areas: the Pearl River Estuary (PRE) and the Vietnam Upwelling Area (VUA). The authors apply the Synergistic-Unique-Redundant Decomposition (SURD) method to quantify the information contributions of multiple physical drivers to Chl-a anomalies. Although the contrasting Chl-a responses to MHWs between these two areas have been documented in previous studies, the application of SURD provides a new perspective for interpreting the underlying mechanisms, which is a methodological innovation in this field. The manuscript is generally well structured and clearly written. However, several important issues need to be addressed before the manuscript can be accepted for publication.

Response: Thank you for the reviewer's positive assessment of our manuscript and for the constructive comments. We have revised the manuscript accordingly, as detailed in the point-by-point responses below.

Major Comment 1:

While the authors have applied a new methodological framework to provide a fresh perspective on the mechanistic drivers of Chl-a anomalies, the results (especially in the VUA) remain largely consistent with previously established understanding. As the authors state in the Introduction: "A key scientific question remains unresolved: are Chl-a anomalies during MHWs mainly driven by direct thermal effects, or by concurrent changes in the physical environment?" In my opinion, the most valuable contribution would be to quantitatively isolate the thermal effect (e.g., as a percentage contribution) rather than merely concluding that temperature is not dominant while other processes are. The prevailing influence of physically driven nutrient supply on phytoplankton responses has already been documented in the literature (e.g., Zhan et al., 2023; Noh et al. 2022). Thus, I suggest that the authors explicitly quantify the thermal contribution using the SURD, as this would represent the genuinely new and insightful outcome of the study.

Zhan, W. K., Y. Zhang, Q. Y. He, et al. Shifting responses of phytoplankton to atmospheric and oceanic forcing in a prolonged marine heatwave. *Limnol Oceanogr*, 2023, 68, 1821-1834.

Response:

Thanks for this insightful comment. Following the reviewer's suggestion, we now report and clarify the unique information contribution of SST_CUM in both study regions from the SURD decomposition.

With the SURD framework, the unique component of a specific variable represents predictive information attributable to that specific variable alone and separable from the other variables. In our study, the SURD analysis did not detect a unique information contribution from SST_CUM in either the VUA or the PRE. In other words, within the selected predictor subsets, SST_CUM did not provide predictive information that could be uniquely separated from the other physical variables. However, SST_CUM remained involved in synergistic terms with other physical variables (Figs. 5b and 8b). Because synergistic information is jointly attributable to multiple predictors, these terms cannot be uniquely partitioned into an additional percentage

contribution attributable to SST_CUM alone. Accordingly, the absence of a detected unique contribution does not imply an absence of thermal involvement in the Chl-a response.

This distinction between the absence of a detected unique contribution and the synergistic involvement of SST_CUM has been clarified in Sects. 3.3.1 and 3.3.2 (Lines 282–286 and Lines 348–351), and the corresponding interpretation has also been incorporated into the Conclusions (Sect. 4, Lines 524–525).

Changes in the manuscript:

Sect. 3.3.1 (Suppressed upwelling in the VUA), Lines 282–286:

“The SURD analysis (Fig. 5b) detected no unique information contribution from SST_CUM within the selected VUA variable subset, whereas EPV showed the largest unique information contribution (12.9 %). The absence of a detected unique contribution from SST_CUM should not be interpreted as an absence of thermal involvement, because SST_CUM remained involved in synergistic terms with the other selected physical variables.”

Sect. 3.3.2 (Horizontal plume retention in the PRE), Lines 348–351:

“As in the VUA, the SURD analysis detected no unique information contribution from SST_CUM, whereas SSS provided the largest unique information contribution (28.1 %; Fig. 8b). This contrast indicates that cumulative thermal stress did not provide separable predictive information within the selected PRE variable subset, with SSS instead representing the dominant source of unique information.”

Sect. 4 (Conclusions), Lines 524–525:

“In both the VUA and the PRE, SST_CUM showed no unique information contribution within the selected variable subsets but remained involved in synergistic interactions with region-specific physical variables.”

Major Comment 2:

The core interpretation for the positive Chl-a anomaly in the PRE relies on the retention of low-salinity Pearl River plume water, which is presumed to supply nutrients that stimulate phytoplankton growth. However, this interpretation appears rather speculative given the current evidence: no direct nutrient data (e.g., nitrate, phosphate, silicate) are presented, nor are optical properties. Salinity is used as a physical tracer, but in eutrophic estuarine systems, low salinity does not always equate to high nutrient availability. In addition, the negative SSS anomaly in the PRE may be associated with enhanced river runoff in the Pearl River Delta (PRD) or increased precipitation in the PRE. The authors should also check the precipitation anomaly in the PRD (pre-MHW) or PRE (during MHWs). Moreover, positive Chl-a anomalies could also arise from reduced grazing, or other processes associated with community changes. Beyond perturbing phytoplankton Chl-a (or biomass), MHWs can substantially reshape phytoplankton community composition (Arteaga and Rousseaux, 2023; Zhan et al., 2026). In coastal waters such as the Pearl River Estuary, MHWs can increase the probability of algal blooms by promoting the reproductive advantage of certain phytoplankton species (Yang et al., 2026). The authors acknowledge this limitation in Section 4.3, but the Results and Discussion sections present the nutrient pathway as a relatively firm conclusion. Therefore, I recommend that the authors: (a) check the precipitation anomalies in the PRD and PRE to further confirm the interpretation; (b) expand the discussion of what the high

causality leak may represent (e.g., missing biological and other processes); and (c) tone down causal language in the abstract and conclusions regarding the PRE.

Arteaga, L. A., and C. S. Rousseaux. Impact of Pacific Ocean heatwaves on phytoplankton community composition. *Commun Biol*, 2023, 6(1), 263.

Zhan, W., Zhang, Y., He, Q., et al. Global responses of phytoplankton size structure to marine heatwaves. *Global Biogeochemical Cycles*, 2026, 40, e2025GB008854.

Yang, S., Feng, L., Dai, Y., et al. Phytoplankton blooms in the coastal seas around China increase in response to warming. *Journal of Geophysical Research: Oceans*, 2026, 131, e2025JC022348.

Response:

We agree with the reviewer that the original interpretation of the PRE mechanism was not sufficiently supported by available evidence. We have addressed this concern in three respects.

I. Precipitation anomalies in the PRD and PRE

Following the reviewer's suggestion, a precipitation diagnostic for both the PRE and the nearby PRD land region has been added. Local precipitation over the PRE did not show positive anomalies during summer MHWs, and precipitation over the PRD likewise showed no systematic enhancement before or around regional MHW establishment (Fig. S2). These results argue against enhanced precipitation as the primary explanation for the observed nearshore freshening. Therefore, variability in river discharge cannot be excluded. However, a consistent long-term daily observational record covering the full study period was not available, precluding a direct assessment of river-discharge variability. The precipitation analysis and its interpretation are now presented in Sect. 3.3.2 (Lines 357–360) and Fig. S2.

II. Interpretation of the relatively high causality leak in the PRE

We also expanded the discussion of the relatively high causality leak in the PRE. In the revised Sect. 3.5 (Lines 475–485), we clarify that the leak represents information or variability in future Chl-a that is not resolved by the selected physical variables and cannot be assigned to any single missing process. Several processes that are not explicitly represented in the present SURD analysis could contribute to this unresolved variability, including suspended-sediment-related light limitation, changes in grazing pressure, MHW-related changes in phytoplankton community composition and size structure, and unresolved nutrient and other biogeochemical processes. Observational and finite-sample uncertainty may also contribute. We therefore interpret the larger PRE leak as reflecting multiple unresolved processes and sources of uncertainty rather than as evidence for any specific missing mechanism.

III. Revision of the PRE mechanism and causal wording

We revised the description of the PRE mechanism throughout the manuscript. In Sect. 3.3.2, the negative SSS anomalies are now described as being consistent with enhanced influence or local retention of low-salinity Pearl River plume water, rather than as direct evidence of plume retention. We also state explicitly that, although nutrient concentrations in the PRE often covary negatively with salinity, nutrients were not

directly observed during the MHW events. The proposed nutrient-support pathway is therefore treated as an inference rather than a directly demonstrated mechanism.

The associated revisions are present in Sect. 3.4, the Fig. 11 caption, Sect. 4 (Conclusions), and the Abstract (Lines 17–21). Across these sections, the hydrographic observations are used to support a physically consistent plume-influence/retention interpretation, whereas the associated nutrient pathway and its contribution to the positive Chl-a anomalies are described more cautiously.

Changes in the manuscript

Abstract, Lines 17–21:

“In the Pearl River Estuary, enhanced incident shortwave radiation promoted rapid surface warming, while weakened wind-driven export favoured the nearshore retention of low-salinity plume water. The SURD results suggest that retained plume water likely strengthened surface-layer stratification and maintained relatively nutrient-rich surface conditions, potentially allowing plume retention to act synergistically with cumulative heat stress and favouring positive Chl-a anomalies. However, the associated nutrient pathway remains inferred rather than directly demonstrated.”

Sect. 3.3.2 (Horizontal plume retention in the PRE), Lines 356–360:

“Together, these spatial patterns support an enhanced influence or local retention of low-salinity Pearl River plume water near the coast. Precipitation anomalies provide little support for enhanced rainfall as the source of this freshening: local PRE precipitation did not increase during summer MHWs, and nearby PRD land precipitation likewise showed no systematic increase around regional MHW establishment (Fig. S2).”

Lines 361–364:

“In the eutrophic PRE, nutrient concentrations often exhibit a negative correlation with salinity (Dai et al., 2008; Niu et al., 2020), so retention of Pearl River plume water could also maintain relatively nutrient-rich surface conditions. Because nutrient concentrations were not directly observed during the MHW events, this nutrient pathway remains inferred rather than directly demonstrated.”

Sect. 3.4 (Contrasting regional responses to the western North Pacific subtropical high), Lines 435–441:

“These conditions favour nearshore retention of low-salinity river plume water, consistent with the negative SSS anomalies in the plume-affected region (Fig. 9f). The absence of enhanced precipitation over the PRE and nearby PRD around these events further argues against anomalous rainfall as the primary cause of the nearshore freshening (Fig. S2). In the eutrophic PRE, retention of plume water could maintain favourable nutrient conditions for positive Chl-a anomalies, although this nutrient pathway was not directly resolved in the present analysis. Together, these processes provide a physically consistent framework for the simultaneous occurrence of elevated temperatures and positive Chl-a anomalies in the PRE, linking radiative warming with wind-regulated plume retention and a plausible nutrient-mediated response.”

Sect. 3.5 (Causal leakage and uncertainty in SURD-based interpretation), Lines 475–485:

“Several processes affecting Chl-a during MHWs therefore remain unresolved. In the turbid PRE, variations in suspended sediment and light availability may constrain phytoplankton growth and modify Chl-a variability (Lu and Gan, 2015). Changes in grazing pressure may alter Chl-a accumulation independently of bottom-up nutrient forcing, and microzooplankton grazing is known to represent an important phytoplankton loss pathway in coastal waters influenced by the Pearl River (Chen et al., 2009). MHWs can also alter phytoplankton community composition and size

structure, potentially modifying the aggregate Chl-a response (Arteaga and Rousseaux, 2023; Zhan et al., 2026). In coastal waters around China, including the Pearl River Delta, warming and MHWs have also been associated with changes in bloom occurrence, suggesting that biological responses to MHWs may extend beyond the physical pathways represented by the selected physical variables (Yang et al., 2026). These processes are plausible contributors to the larger causality leak in the PRE, although their individual contributions cannot be separated from the leak term in the present analysis.”

Fig. 11 caption, Lines 453–455:

“(b) In the PRE, enhanced shortwave radiation promotes surface warming and MHW development, while weakened wind-driven offshore transport favours nearshore retention of low-salinity river plume water, providing conditions associated with a positive Chl-a anomaly.”

Sect. 4 (Conclusions), Lines 511–515:

“Precipitation did not increase during the MHW events, further supporting plume retention rather than anomalous rainfall as a cause of the observed nearshore freshening. Enhanced shortwave radiation favoured rapid surface warming and MHW development in this shallow shelf region, while weakened wind-driven export favoured the nearshore retention of low-salinity plume water. This low-salinity surface layer likely strengthened upper-ocean stratification and hence favoured the positive surface Chl-a anomalies, although the associated nutrient pathway was not directly resolved.”

Fig. S2 in the Supplement:

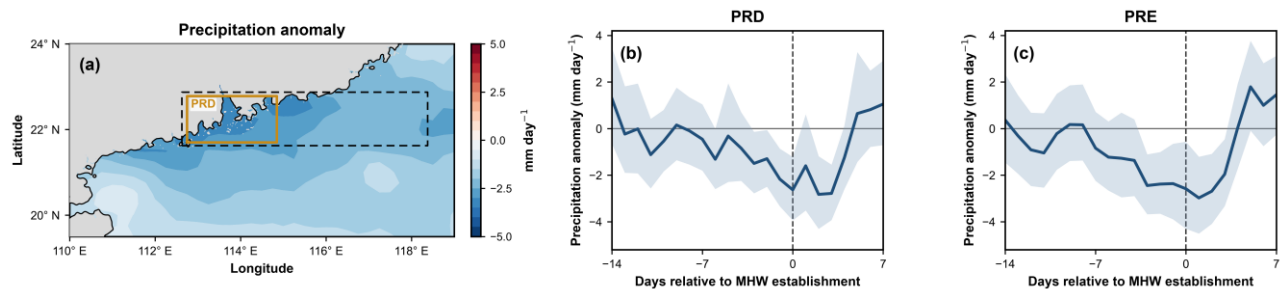


Figure S2. Precipitation anomalies associated with PRE summer MHWs. (a) Spatial composite of precipitation anomalies; the dashed and orange boxes mark the PRE analysis region and the PRD land region, respectively. (b, c) Composite precipitation anomalies over the PRD land region and PRE ocean region, respectively, relative to the regional MHW establishment date (day 0). Shading denotes the 95 % confidence interval.

Major Comment 3:

This study focuses primarily on the impacts of summer MHWs on Chl-a in the two areas. However, whether the mechanistic conclusions drawn here are transferable to other seasons remains to be validated. I would suggest that the authors either conduct a parallel analysis for other seasons to assess the seasonal dependence of their findings, or revise the title to clearly frame the conclusions within the summer context.

Response:

Thanks for pointing out this issue. The seasonal composites of Chl-a anomalies during MHWs show that the contrast between the PRE and VUA is far more pronounced in summer than in other seasons (Fig. 4).

Therefore, the analysis of the underlying mechanisms in this study focuses on summer. Following the reviewer's suggestion, we revised the title and corresponding manuscript text to consistently frame the mechanistic conclusions in the context of summer MHWs.

Changes in the manuscript:

Title:

“Contrasting physical drivers of chlorophyll-a responses to summer marine heatwaves in the South China Sea”

Sect. 3.2 (Chl-a responses to MHWs), Lines 252–253:

“We therefore focus the subsequent mechanistic analysis on summer, when the clearest contrast emerges between the PRE and VUA.”

Sect. 3.3 title:

“Regional physical pathways of Chl-a responses during summer MHWs”

Sect. 4 (Conclusions), Lines 525–526:

“These findings highlight the importance of physical–biological coupling in shaping Chl-a responses to MHWs.”

Minor Comment 1 (Line 48):

Please add more references on MHW spatiotemporal evolution in the SCS, e.g., Yao and Wang (2024) and Yuan et al. (2024).

Yao, Y., & Wang, C. Subsurface marine heatwaves in the South China Sea. *Journal of Geophysical Research: Oceans*, 2024, 129, e2024JC021356.

Yuan, T., Zhang, J., Yang, S., et al. Vertical structures of marine heatwaves in the South China Sea: Characteristics, drivers and impacts on chlorophyll concentration. *Journal of Geophysical Research: Oceans*, 2024, 129(12), e2024JC021091.

Response:

Thank you for this suggestion. We have expanded the Introduction to incorporate recent studies on the spatiotemporal evolution of MHWs in the South China Sea, particularly their subsurface and vertical characteristics. Specifically, we added Yao and Wang (2024) and Yuan et al. (2024), which extend previous descriptions of SCS MHWs from the sea surface to their subsurface and vertical structures.

Changes in the manuscript:

Sect. 1 (Introduction), Lines 54–56:

“Recent studies have extended this characterization below the sea surface, revealing pronounced subsurface intensification and diverse vertical structures of MHWs in the SCS (Yao and Wang, 2024; Yuan et al., 2024).”

Minor Comment 2 (Line 50):

The authors should briefly expand upon the key findings of previous studies rather than merely citing them. In addition, relevant references such as Zheng et al. (2024) and Yuan et al. (2024) should be incorporated to strengthen the literature review.

Yuan, T., Zhang, J., Yang, S., et al. Vertical structures of marine heatwaves in the South China Sea: Characteristics, drivers and impacts on chlorophyll concentration. *Journal of Geophysical*

Research: Oceans, 2024, 129(12), e2024JC021091.

Zheng, J., Xiu, P., Zeng, L., et al. Phytoplankton response to the record-breaking marine heatwave in the summer of 2020 in the South China Sea. *Journal of Geophysical Research: Oceans*, 2024, 129(10), e2024JC021275.

Response:

Thank you for this suggestion. We have expanded the relevant literature review in the Introduction to briefly summarize previous findings on the regional and vertical variability of Chl-a responses to MHWs in the SCS, rather than only citing these studies. We also incorporated Zheng et al. (2024) and Yuan et al. (2024) into the discussion of vertical Chl-a responses to MHWs.

Changes in the manuscript:

Sect. 1 (Introduction), Lines 40–43:

“During the record-breaking 2020 SCS MHW, reduced surface Chl-a coincided with increased subsurface Chl-a (Zheng et al., 2024), and Chl-a responses differed among MHWs with different vertical structures (Yuan et al., 2024). MHW-related changes in vertical Chl-a structure have also been reported in other oceanic regions (Li et al., 2025). Surface Chl-a alone may therefore not fully capture the underlying biological response.”

Sect. 1 (Introduction), Lines 58–59:

“Previous studies have shown that Chl-a responses to MHWs in the SCS are spatially heterogeneous and vary among different oceanographic settings (Chen et al., 2024; He et al., 2023).”

Minor Comment 3 (Lines 122-123):

The rationale for selecting 1982-2011 as the MHW climatological baseline is not clearly justified. Since the phytoplankton data are only available from 1998 onwards, using a baseline period that overlaps more closely with the study period (e.g., 1995-2024) would seem more appropriate and consistent. Could the authors clarify this choice?

Response:

Thank you for raising this issue. In Sect. 2.3.1, we have clarified that the 1982–2011 period was used as a fixed 30-year climatological baseline for MHW detection, consistent with the fixed-baseline framework commonly used in MHW studies (e.g., Hobday et al., 2016; Chiswell, 2022). The Chl-a data availability from 1998 onward determines the analysis period for biological responses. These two periods serve distinct methodological roles and do not need to coincide.

We realize that a fixed 1982–2011 climatological baseline does not account for effects of long-term warming on the MHW threshold. Thus, we added a brief statement that the fixed threshold does not adjust to long-term warming of the background climate.

Changes in the manuscript:

Sect. 2.3.1 (MHW identification and metric calculation), Lines 140–144:

“The period 1982 to 2011 was used as a fixed 30-year climatological baseline for calculating daily thresholds, consistent with the fixed-baseline approach widely used in MHW studies (Hobday et al., 2016; Chiswell, 2022). MHW detection was then applied to SST time series from 1998 to 2024. One limitation of this approach is that the

climatological threshold remains fixed and therefore does not adjust to the long-term warming of the background climate (Chiswell, 2022).”

Minor Comment 4 (Line 184):

"high-frequency area" → "high-frequency MHW area".

Response:

Thanks for the suggestion. We have revised it (Sect. 3.1, Line 232).

Minor Comment 5 (Line 208):

In Figure 4, the stippling indicating statistically significant differences appears to have been applied at a 1° spatial resolution, whereas the underlying Chl-a and SST data are at 0.25° resolution. These resolutions should be made consistent. If the 0.25° stippling is too dense for visual clarity, I would suggest displaying only the data points that pass the significance test, rather than applying a coarser significance mask.

Response:

Thank you for pointing this out. The significance tests were performed on the 0.25° analysis grid, but the stippling in the original figure was subsampled for visual clarity, giving the appearance of a coarser resolution. We have revised Fig. 4 to display all significant grid points at the original 0.25° analysis resolution, consistent with the underlying analysis grid.

Changes in the manuscript:

Fig. 4: The significance stippling has been revised to display all significant grid points at the 0.25° analysis resolution. The figure caption remains unchanged.

Minor Comment 6 (Line 212):

Why was SST_CUM (cumulative SST intensity) chosen to represent thermal stress, rather than using SST intensity directly? The use of SST_CUM implies an event-integrated metric; however, it is unclear whether the other variables (such as SSS and SLA) were also averaged over the MHW event duration, or whether they were similarly expressed as cumulative intensities. Please clarify this point.

Response:

Thank you for raising this point. We have clarified both the rationale for using SST_CUM and the temporal construction of the variables entering the SURD analysis.

For a persistent extreme warming event, cumulative thermal stress is usually more informative for assessing the warming effects on marine organisms and ecosystems than single-day or event-averaged thermal stress. For example, long-duration and short-duration MHWs may have the same mean or maximum SST intensity, yet the longer-lasting event can potentially induce more severe biological responses because of its prolonged thermal exposure. For this reason, SST_CUM was chosen to characterize the potential impacts of MHWs on Chl-a. The other physical variables were not averaged over the MHW duration or converted to cumulative

metrics. They were represented by their concurrent daily anomalies at time t , whereas SST_CUM represented the accumulated thermal stress from MHW onset to the same day. Thus, SST_CUM characterized cumulative thermal conditions, while SSS, SLA, EPV, winds, and the other candidate variables characterized the concurrent physical environment. All environmental anomalies were calculated relative to their respective 1998–2024 daily climatologies.

Changes in the manuscript:

Sect. 2.3.1 (MHW identification and metric calculation), Lines 152–154:

“Separately, for the SURD analysis, we constructed a running cumulative SST anomaly metric (SST_CUM) to represent the thermal exposure accumulated from MHW onset to each MHW day. SST_CUM therefore evolves over the progression of an event rather than representing a single event-level value.”

Sect. 2.3.2 (SURD causality analysis), Lines 186–188:

“SST_CUM at time t represented the accumulated thermal conditions from MHW onset to the current day, whereas the other predictors were represented by their concurrent daily anomalies at t and were not averaged over the MHW duration or converted to cumulative metrics.”

Minor Comment 7:

Can the unique contribution of SST_CUM be quantified and shown, e.g., in Figure 5b?

Response:

Thank you for this suggestion. The SURD analysis did not detect a unique information contribution from SST_CUM in either the VUA or the PRE. We have therefore revised the Results to report this finding explicitly for both regions.

We did not add the SST_CUM unique term to Figs. 5b and 8b because these panels show only the six largest non-leak SURD terms. Because no unique contribution from SST_CUM was detected, adding this term would not provide additional graphical information. Instead, we report the SST_CUM unique-information result directly in the corresponding Results text, where its interpretation can be stated clearly.

Changes in the manuscript:

Sect. 3.3.1 (Suppressed upwelling in the VUA), Lines 282–286:

“The SURD analysis (Fig. 5b) detected no unique information contribution from SST_CUM within the selected VUA variable subset, whereas EPV showed the largest unique information contribution (12.9 %). The absence of a detected unique contribution from SST_CUM should not be interpreted as an absence of thermal involvement, because SST_CUM remained involved in synergistic terms with the other selected physical variables.”

Sect. 3.3.2 (Horizontal plume retention in the PRE), Lines 348–351:

“As in the VUA, the SURD analysis detected no unique information contribution from SST_CUM, whereas SSS provided the largest unique information contribution (28.1 %; Fig. 8b). This contrast indicates that cumulative thermal stress did not provide separable predictive information within the selected PRE variable subset, with SSS instead representing the dominant source of unique information.”

Minor Comment 8 (Line 267):

How exactly was N^2 calculated in this study?

Response:

Thank you for pointing this out. We have revised Sect. 2.2 to explicitly describe how the squared Brunt–Väisälä frequency (N^2) was calculated from the temperature and salinity profiles (Lines 109–113).

Changes in the manuscript:

Sect. 2.2, Lines 109–113:

The squared Brunt–Väisälä frequency (N^2) was derived from the temperature and salinity profiles. Following the linear equation of state approximation (Gill, 1982), density was approximated as $\rho = \rho_0[1 - \alpha(T - T_0) + \beta(S - S_0)]$ with $\rho_0 = 1025 \text{ kg m}^{-3}$, $\alpha = 1.7 \times 10^{-4}$, $\beta = 7.6 \times 10^{-4}$. Here, T and S denote seawater temperature and salinity, respectively, and $T_0 = 25 \text{ }^\circ\text{C}$ and $S_0 = 35$ are reference values. N^2 was calculated from the vertical density gradient as $N^2 = (g/\rho_0) \partial\rho/\partial D$, where D is depth increasing downward and $g = 9.81 \text{ m s}^{-2}$.

Minor Comment 9 (Lines 308-309):

This statement is too categorical. A decrease in SSS does not necessarily indicate plume retention. The authors should examine variations in river discharge or precipitation during MHWs to better constrain the mechanism.

Response:

Thank you for this comment. We have revised the original statement so that the negative SSS anomalies are described as being consistent with enhanced plume influence or local retention, rather than as direct evidence of plume retention.

We also examined precipitation over the PRE and nearby PRD. Precipitation over the PRE did not increase during summer MHWs, and precipitation over the PRD showed no systematic enhancement around the onset of regional MHWs (Fig. S2). These results do not support enhanced rainfall as the primary cause of the nearshore freshening. Variability in river discharge cannot be excluded. This issue and the associated precipitation analysis are discussed in more detail in our response to **Major Comment 2**.

Changes in the manuscript:

Sect. 3.3.2 (Horizontal plume retention in the PRE), Lines 356–360:

“Together, these spatial patterns support an enhanced influence or local retention of low-salinity Pearl River plume water near the coast. Precipitation anomalies provide little support for enhanced rainfall as the source of this freshening: local PRE precipitation did not increase during summer MHWs, and nearby PRD land precipitation likewise showed no systematic increase around regional MHW establishment (Fig. S2).”

Minor Comment 10 (Lines 394-398):

I would recommend that the authors devote additional space to discussing the potential drivers of the high causality leak in the PRE. In particular, biological processes such as grazing pressure and changes in phytoplankton community composition during MHWs should be considered as plausible contributors that are not captured by the current physical driver set.

Response:

Thank you for this comment. This issue has been addressed as part of our response to Major Comment 2 above. We have expanded Sect. 3.5 to discuss the relatively high causality leak in the PRE and its possible sources, including changes in grazing pressure and MHW-related changes in phytoplankton community composition and size structure. We also clarify that these processes are plausible contributors to the unresolved leak rather than individually resolved components of the SURD decomposition. Please see our response to Major Comment 2 and the corresponding revisions in Sect. 3.5 (Lines 461–462 and 477–481) for details.

Changes in the manuscript:

Sect. 3.5 (Causal leakage and uncertainty in SURD-based interpretation), Lines 461–462:

“This residual uncertainty may arise from processes not represented by the selected variables, as well as from observational and finite-sample uncertainty, and therefore cannot be assigned to any single missing process.”

Sect. 3.5, Lines 477–481:

“Changes in grazing pressure may alter Chl-a accumulation independently of bottom-up nutrient forcing, and microzooplankton grazing is known to represent an important phytoplankton loss pathway in coastal waters influenced by the Pearl River (Chen et al., 2009). MHWs can also alter phytoplankton community composition and size structure, potentially modifying the aggregate Chl-a response (Arteaga and Rousseaux, 2023; Zhan et al., 2026).”