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.

Major Comments:

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.

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.

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.

Minor Comments:

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.

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.

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?

4. Line 184: "high-frequency area" → "high-frequency MHW area".

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.

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.

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

8. Line 267: How exactly was N^2 calculated in this study?

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.

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.