RESPONSE TO CC1'S COMMENTS - Mr. Longyu Huang

Manuscript Title: Internal tide signatures on surface chlorophyll concentration in the Brazilian Equatorial Margin

Manuscript ID: EGUSPHERE-2025-2307

Journal: Ocean Science

Dear Mr. Longyu Huang,

Thank you very much for your thoughtful and constructive comments. We carefully considered each of your suggestions and have addressed them in detail in the following pages, along with a description of the corresponding revisions made to the manuscript.

Sincerely,

Dr. Carina Regina de Macedo, Dr. Ariane Koch-Larrouy, Prof. José Carlos Bastos da Silva, Dr. Jorge Manuel Magalhães, Dr. Fernand Assene, Dr. Manh Duy Tran, Dr. Isabelle Dadou, Mr. Amine M'Hamdi, Dr. Trung Kien Tran, and Dr. Vincent Vantrepotte

Note: In the revised manuscript, all modifications are marked in red.

CC1'S COMMENTS:

In this manuscript, the authors investigate the influence of tides on chlorophyll-a (CHL) variability in the Brazilian Equatorial Margin using two types of daily remotely sensed CHL data from 2005 to 2021. Although the studies of internal tides (ITs) in this region have been widely documented, the ITs contributions on the marine ecology are rarely reported. This is an interesting topic and suitable for the journal Ocean Science. Overall, the current manuscript is well organized and written, the results are present clearly and provide valuable insights into the ecological impacts of ITs. Now, I recommend a minor revision and some questions and suggestions for the authors to improve the manuscript.

Specific comments:

1. The introduction is well written and clear, and summarizes the relevant research on internal tides in this region. However, in the main text, the authors mention lots of elements about the bathymetry, generation sites and pathways of internal tides in the Brazilian Equatorial Margin that referred from other studies. I suggest the authors give a figure to present the overview for the study region.

Response: As suggested by the community commentator, we added a figure in the Introduction providing an overview of the study area (see the figure below).

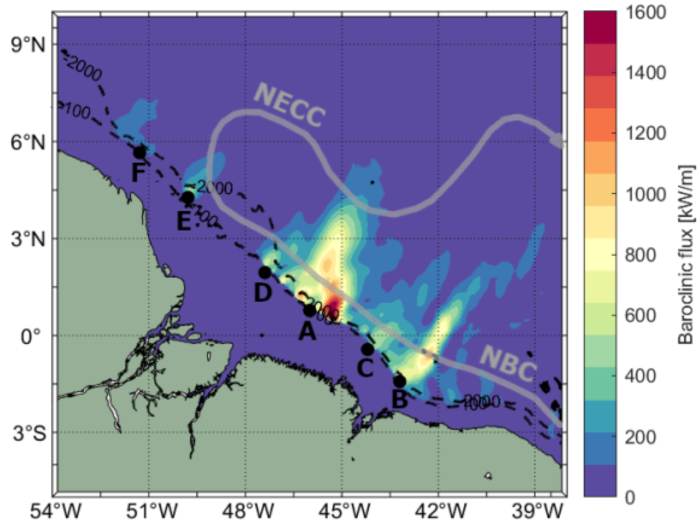

Figure 1. Baroclinic flux over the BEM. IT generation sites are labeled from A to F along the shelf break. The black dashed line and black dots represent the bathymetric contours of -100 m and -2000 m, and the generation points, respectively, following Assene et al. (2024). The North Brazil Current (NBC) and the NECC are highlighted with thick gray arrows.

2. In Methods 2.2, why the average period is 15 days?

Response: We chose a 15-day averaging window for two main reasons. First, we aimed to use a period close to the fortnightly tidal signal (14.7 days), while keeping an odd-numbered window so that the illustrative case day remained centered. Second, we empirically verified that longer averaging windows tended to smooth out the signal of interest, leading to loss of relevant variability.

3. In Methods 2.3, the physical mechanisms of wavelet analysis should be explained and say somewhat to explain the meanings of high or low Power in Figure 5 (a-b).

Response: The spectral energy at a period of ~14.7 days (the fortnightly signal) indicates variability in the time series associated with fortnightly oscillations. To clarify this point, we have added further explanation in Section 2.3 (Wavelet analysis):

lines 127-130: In regions where M2 and S2 tidal constituents dominate, their nonlinear interaction generates the MSf (Lunisolar Synodic Fortnightly) oscillation, with a period of approximately 14.7 days. The MSf corresponds to the neap–spring tidal cycle, a phenomenon of great importance in tidal dynamics and a major physical factor influencing coastal and marine environments. Wavelet analysis was therefore applied to identify and quantify this fortnightly variability in the CHL and SST time series.

4. In Methods 2.4, the tides in single ITs generation sites are extracted for the calculation of Tide Composition *f (S, N)*. In Fig. 6-9, there are several ITs generation sites

and pathways, such as pathway A, B and C, I wonder if the *f (S, N)* is computed using tides extracted in one site or all sites?

Response: We appreciate the reviewer's question. The f(S,N) was computed using the tidal elevation extracted at the IT generation point A. However, we also calculated the phase lag of the tidal signal between generation points A and B, and A and C, which were 10.3° (≈ 0.36 h) and 3.65° (≈ 0.13 h), respectively. These small phase differences indicate that the tidal phase is nearly coherent among these sites, particularly considering that our methodology uses a three-day window centered on the spring/neap tide days.

5. In Figure 2 and 3, I suggest the author added the bathymetric contours for the clarity. Besides, the locations of points A and D are hard to distinguish, the point color should be changed. What the two black dashed lines in the lower left mean? The locations of mode-1 and 2 ISWs should be labeled in Figure 2 and 3 (d).

Response: Following the suggestions of CC1, we enhanced the contrast of points A and D as well as the internal solitary wave signatures. The purpose of Figure 2(d) is to show the MODIS-Terra image and the appearance of the ISW signatures within it. Labeling their locations directly on the figure would make the signatures even more difficult to visualize. The black dashed lines represent bathymetric contours; however, since they were not labeled, we agree with the CC1 that their meaning was unclear. To address this, we have now labeled the bathymetric contours. The revised figures are provided below.

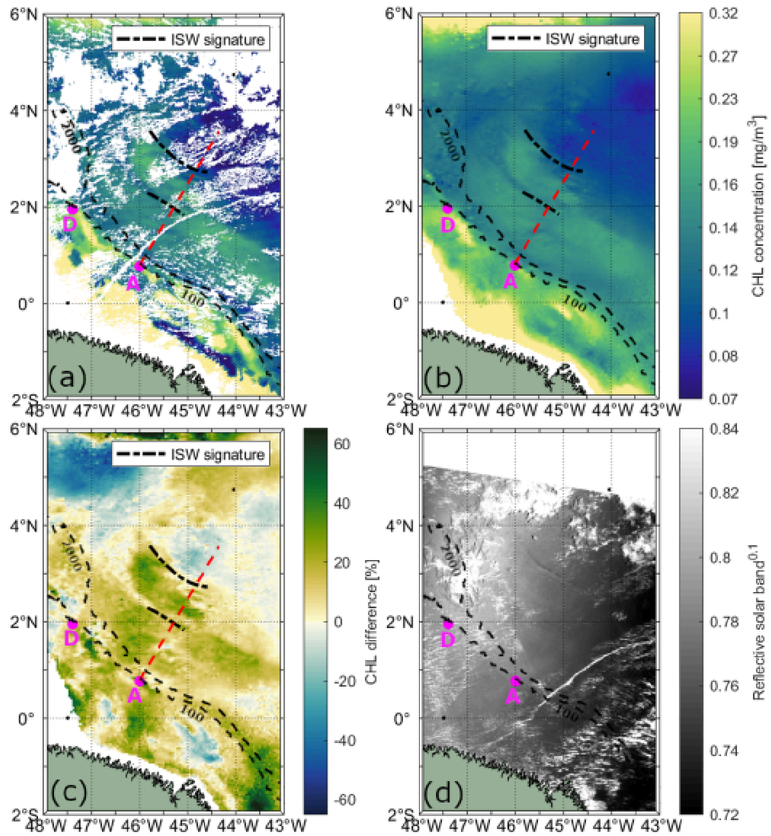

Figure 3. Illustrative case I showing the influence of ITs on CHL concentration on September 28, 2007. CHL concentration data is shown from (a) MODIS-Aqua and (b) Globcolour product. (c) CHL relative difference (%) between the CHL on the day of ISW occurrence and the 15-day mean CHL centered on that day (see, Equation 1) from GlobColour product. (d) ISW signatures observed in the MODIS-Terra image. The red dashed line and magenta dots indicate the IT pathway and generation points, respectively, based on Assene et al. (2024). Black dashed lines mark the ISW signatures visible in the MODIS-Terra image.

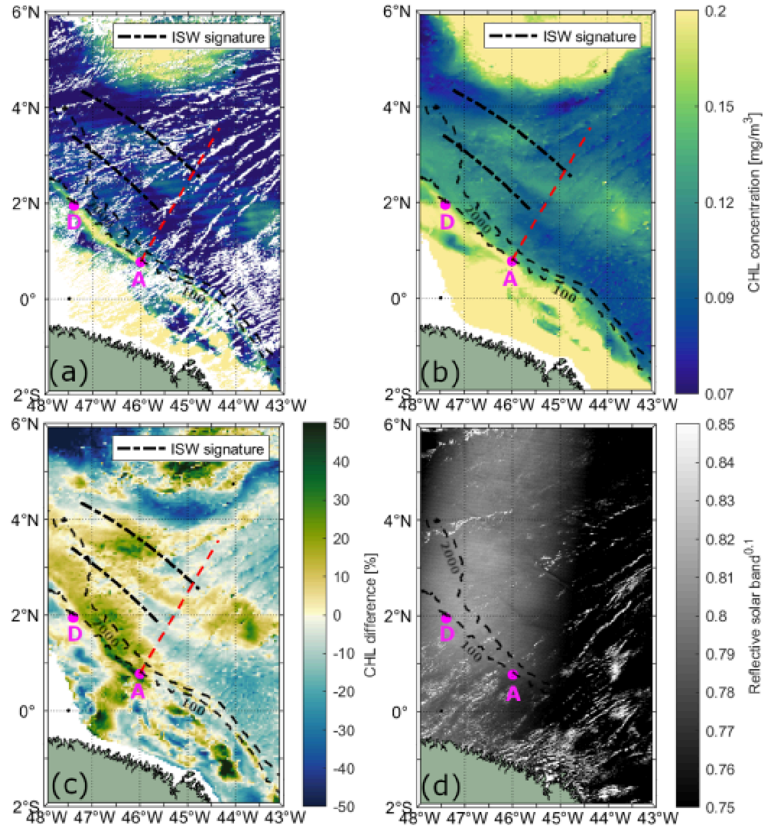

Figure 4. Illustrative case II showing the influence of ITs on CHL concentration on October 12, 2018. CHL concentration data is shown from (a) MODIS-Aqua and (b) Globcolour product. (c) CHL relative difference (%) between the CHL on the day of ISW occurrence and the 15-day mean CHL centered on that day (see, Equation 1) from GlobColour product. (d) ISW signatures observed in the MODIS-Terra image. The red dashed line and magenta dots indicate the IT pathway and generation points, respectively, based on Assene et al. (2024). Black dashed lines mark the ISW signatures visible in the MODIS-Terra image.

6. Line 210: Which IT generation site should be clarified.

Response: Indeed, this information was previously missing from the manuscript. It refers to the IT generation site A. We appreciate your attention to this detail.

lines 204-205: For illustrative case II, two peaks are found at 122 km (8%) and 262 km (7%), respectively, 62 km and 202 km from the IT generation site A

7. Line 213: Figure 4 show that signal filtered mode-2 IT is more closely with the original signal of CHL different. If this mean that the variation of CHL is mainly caused by mode-2 IT? I wonder why the smaller horizontal and vertical scale of mode-2 IT could induce greater variation of CHL.

Response: We thank the reviewer for this question. The closer correspondence between the mode-2 IT filtered signal and the original CHL difference signal does not necessarily indicate that CHL variability is mainly driven by mode-2 internal tides. But it suggests that CHL is more sensitive to the processes typically associated with higher internal tide modes. Higher modes are more closely linked to enhanced vertical shear and mixing, which can promote nutrient entrainment into the euphotic zone and, consequently, variations in chlorophyll concentration. Previous studies have shown that the redistribution of low-mode energy flux to higher modes through interactions with the background circulation provides an important mechanism for driving mixing away from internal tide generation sites. Scattering to higher modes allows for greater vertical propagation and energy dissipation, contributing significantly to deep-ocean mixing (e.g., Kerry et al., 2014). Therefore, we think that the stronger relationship between CHL variability and the mode-2 IT signal likely reflects the greater sensitivity of biological and biogeochemical responses to the enhanced vertical mixing and instability commonly induced by higher-mode internal tides. However, further investigation would be required to confirm if this mechanism is indeed dominant in our study region, as the relative contribution of each mode may vary spatially and seasonally depending on local stratification and bathymetric conditions.

All this information was added in the Discussion section as follow:

lines 359-366: The mean spectral coherence between spring-neap tidal cycle signal and the band-pass filter component is higher for mode-2 than mode-1, considering both GlobColour and MODIS-Aqua data. It can indicate that CHL is more sensitive to the physical processes typically associated with higher internal-tide modes. As discussed in previous studies, the redistribution of low-mode energy flux to higher modes through interactions with the background circulation provides an important mechanism for driving mixing away from internal-tide generation sites; scattering to higher modes allows for greater vertical propagation and energy dissipation (Kerry et al., 2014; Dunphy & Lamb, 2014; Savva et al., 2018; Tuerena et al., 2019; Lahaye et al., 2020; Li et al., 2023).

8. Figure 5: the barotropic and baroclinic energy flux (in c and d) are from NEMO by Assene et al 2024, if the time align with (a) and (b)? Besides, in Line 225, why choose S2 tidal constituent instead of M2?

Response: The depth-integrated barotropic and baroclinic energy fluxes and dissipation derived from the NEMO model using the AMAZOMIX36 configuration represent mean values for the year 2015, and therefore are not time-aligned with panels (a) and (b), which represent mean values from 2005 to 2021.

The S2 component was selected for comparison with the mean Morlet wavelet power within the 14.2–15.2-day period, as the barotropic dissipation is substantially lower than that of baroclinic one in the offshore region.

9. Line 239: where are the three peaks of positive CHL difference?

Response: Figure A2-(a) provides a close-up view that highlights the wave-like pattern in the CHL composite with a 1-day delay. The text has been modified to indicate that, in Figure A2-(a), the three peaks of positive CHL differences related to the spring–neap tidal cycle can be clearly observed:

lines 235:238: Referring to the spring-neap tidal cycle composites with a 1-day delay as a benchmark, Figure 7-(b) illustrates at least three peaks of positive CHL spring-neap tidal cycle difference (please, see in Figure A2-(a) a close-up view highlighting the wave-like pattern in the CHL composite, with 1-day delay is shown).

10. Line 242: Figure 7?

Response: Thank you for pointing that out. You are correct — the figure was initially misnumbered. At the time of your review, it should have been Figure 6; however, since an additional figure was added to the manuscript, it now corresponds to Figure 7.

11. The authors should explain why the mode-2 f is much greater than mode-1 f in Figure 9, while the values of f are equivalent in Figure 7, even though two types of CHL data are used.

Response: We thank the reviewer for this insightful comment. The stronger mode-2 IT signal observed in Figure 9 when using MODIS-Aqua data may be related to differences in spatial resolution and data processing between the two CHL products. MODIS-Aqua provides observations at a higher spatial resolution (1 km) when compared to the Globcolour product (4 km), which can better capture submesoscale features and local gradients associated with mode-2 internal tides. In contrast, the GlobColour product is a merged dataset that combines multiple satellite missions and involves interpolation and smoothing procedures. These processes tend to reduce high-frequency spatial variability, leading to a weaker representation of mode-2 signals. Additionally, differences in sensor calibration and atmospheric correction among the merged datasets may contribute to the smaller mode-2 amplitudes in GlobColour. Despite these differences, both datasets consistently indicate the presence of mode-1 and mode-2 internal tide signals along the IT pathways.

The information on spatial resolution was added to the manuscript as follows:

lines 87-88: CHL data were derived from daily Level 1A acquisitions of the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard the Aqua satellite, covering the period from January 1, 2005, to December 31, 2021, at a spatial resolution of 1 km.

lines 98-99: The GlobColour product was obtained from the Copernicus Marine Service (DOI: 10.48670/moi-00281) for the period from January 1, 2005, to December 31, 2021, at a spatial resolution of 4 km.

12. The display range of the color bar should be uniform. Such as (a-f), (g-h) in Figure 6 and 8, respectively, and Figure A1 (a-b).

Response: As suggested by the community commentator, we standardized the color bars in Figures 6, 8, and A1. The revised figures are provided below.

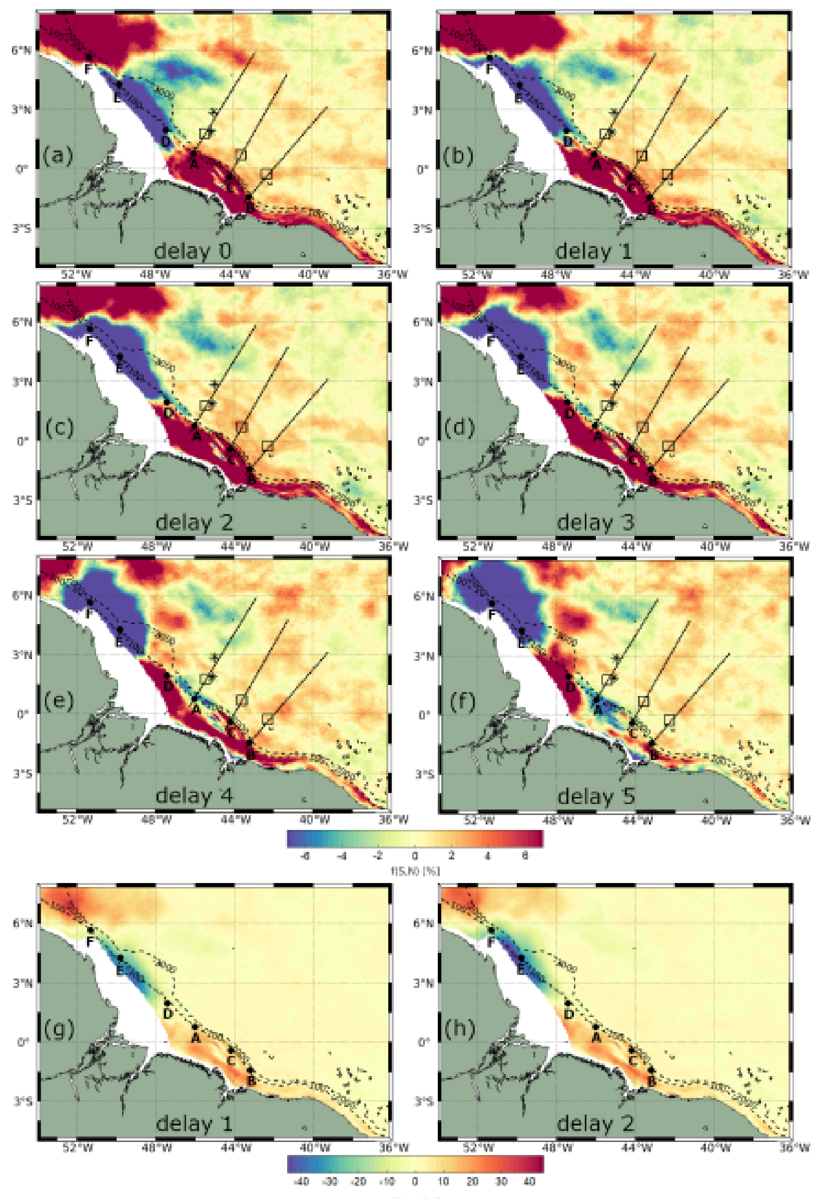

Figure 7. Spring-neap tidal cycle composites of CHL using daily Globcolour product, considering delays of (a-f) 0-5 days. Spring-neap tidal cycle composite map for delay of (g) 1 and (h) 2 days, using a color bar for highlighting the shelf. Areas of high CHL fortnightly power are shown as black rectangles, IT generation points are displayed as black points, IT pathways are shown as black dashed lines according to Assene et al. (2024), and black stars represent the areas of high ISW occurrence according to de Macedo et al. (2023).

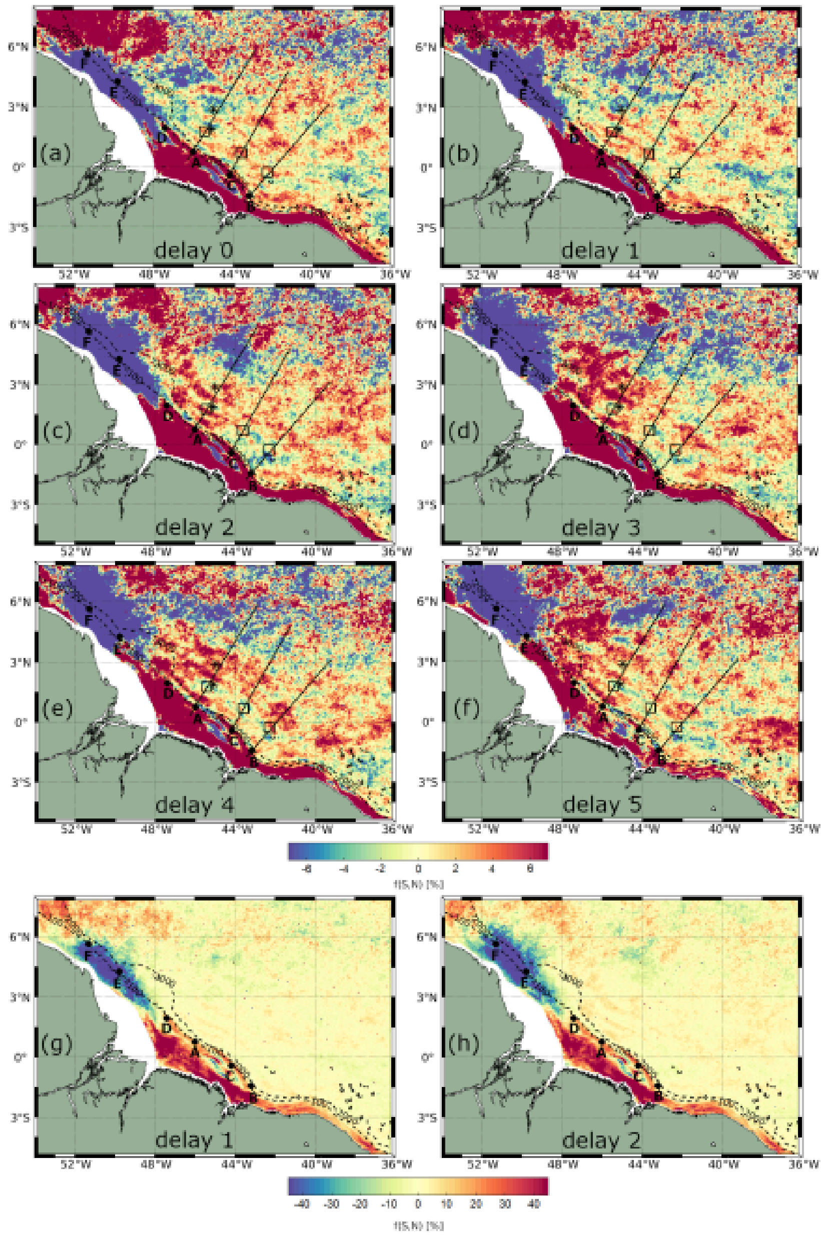

Figure 9. Spring-neap tidal cycle composites of CHL using daily MODIS-Aqua data, considering delays of (a-f) 0-5 days.. Spring-neap tidal cycle composite map for delay of (g) 1 and (h) 2 days, using a color bar for highlighting the shelf. Areas of high CHL fortnightly power are shown as black rectangles, IT generation points are displayed as black points, IT pathways are shown as black dashed lines according to Assene et al. (2024), and black stars represent the areas of high ISW occurrence according to de Macedo et al. (2023).

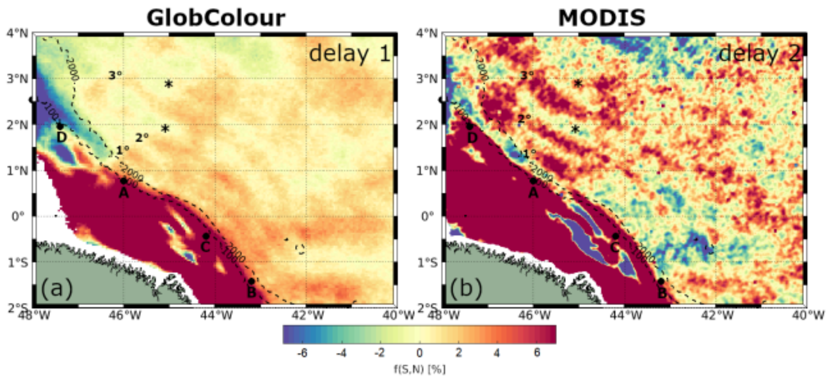

Figure A2. ZOOM of Figures 7 and 9 highlighting the wave-like pattern in the horizontal structure of spring-neap tidal cycle CHL composites for (a) GlobColour, with a 1-day delay, and (b) MODIS-Aqua, with a 2-day delay. IT generation points, as identified by Assene et al. (2024), are indicated by black dots, while areas of high ISW occurrence, based on de Macedo et al. (2023), are marked with black stars. The numbered labels denote the first, second, and third positive peaks in the CHL composites.

We thank the reviewer again for the valuable comments, which have significantly contributed to improving the clarity and accuracy of our manuscript.

REFERENCES

Kerry, C. G., Powell, B. S., & Carter, G. S. (2014). The impact of subtidal circulation on internal-tide-induced mixing in the Philippine Sea. Journal of Physical Oceanography, 44(12), 3209-3224.