RESPONSE TO RC1'S COMMENTS

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

Manuscript ID: EGUSPHERE-2025-2307

Journal: Ocean Science

Dear Reviewer,

We sincerely appreciate your valuable and constructive feedback. Each of your suggestions has been thoroughly evaluated, and the corresponding changes have been incorporated into the manuscript. A detailed explanation of these revisions is provided in the following pages.

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.

REVIEWER 1'S COMMENTS:

The manuscript (MS) makes a comprehensive and detailed analysis to connect wave-like signal in chlrophyll-a satelitte images to internal tide dynamics off the Amazon continental shelf. Although the title and abstract suggest a focus on baroclinic tides, the MS also presents ideas connecting observed patterns to barotropic tides.

Response: We agree with the reviewer that the original manuscript title suggested a focus on baroclinic tides. Therefore, the title has been revised to also incorporate barotropic tides:

Tide signatures on surface chlorophyll concentration in the Brazilian Equatorial Margin

The results are interesting and certainly relevant, but the MS requires extensive reorganization for the main message to come through clearly. The knowledge gap is not well-defined, and in several parts of the document, the arguments are largely speculative and not sufficiently supported by evidence. I recommend major revision. If the speculative aspects are clarified, supported by evidence, or removed, and the MS is restructured, it could make a strong contribution to the literature.

Response: Following the reviewer's suggestion, we revised the Introduction section to more clearly define the knowledge gap. Furthermore, we restructured both the Introduction and

Conclusion sections to better meet the reviewer's expectations. All the speculative parts have been removed from the conclusions. It was retained only in the discussion section, where its speculative nature is explicitly highlighted.

MAJOR CONCERNS

My major concerns relate primarily to structure and terminology:

1. Structure of Introduction and Conclusion:

The introduction reads almost like a discussion. Although the last paragraph mentions the topic of the MS, the knowledge gap or main question is unclear.

Response: The Introduction section has been revised to address the reviewer's expectations.

The knowledge gap is now explicitly stated in the final paragraph of the Introduction. The revised text is provided below:

lines 75-79: Despite the advances made so far, significant gaps remain concerning the impact and spatial extent of tides (particularly baroclinic tides) on CHL concentration and SST in the BEM. In this study, we investigate the fortnightly signal in remote sensing surface CHL concentration, accounting for various delays related to astronomical tidal forcing. To our knowledge, this is the first time that the influence of baroclinic tides on CHL concentration has been demonstrated in the BEM using a long-term remote sensing time series.

Similarly, the conclusion reads like a dicussion and is repetitive compared to Section 4.3. I sugget renaming it Summary and Conclusions.

Response: Following the suggestion of the reviewer, the Section "*5. Conclusions*" was renamed to "*5. Summary and conclusions*". In addition, all discussion elements were removed from the "Summary and Conclusions" section, which has been rewritten accordingly.

2. Terminology:

The use of showcase seems inappropriate in this context. Consider using case study or illustrative case.

Response: We agree with the reviewer's comment and have replaced "showcase" with "illustrative case.

Sunglint should not be used as an adjective.

Response: We thank the reviewer for pointing this out. The manuscript has been carefully revised, and all instances where "sunglint" was previously used as an adjective have been corrected.

Although I think I understand the reason behind the two study cases, the MS should clarify why they are used. It should explicit that they are intended to demonstrate the existence of internal tides in the area, which justifies exptrapolating to a time series of chlorophyll images from Globcolour and MODIS-Aqua.

Response: Thank you for your comment. Following the reviewer's suggestion, we have included this information in the manuscript as follows:

lines 168-179: We selected two illustrative cases to demonstrate how the passage of ITs can influence chlorophyll concentration, thereby justifying the subsequent analysis that extrapolates this effect to a 17-year time series.

Avoid using coloquial terms like "sandwich"; I recommend "to be flanked" instead.

Response: The term "*sandwiched*" has been replaced with "*flanked*" throughout the manuscript.

The term "spring-neap tide" is confusing; I believe you mean "spring-neap tidal cycle". Clarify or define this early in the MS.

Response: Following the reviewer's suggestion, we have replaced the term "spring-neap tide" with "spring-neap tidal cycle" throughout the manuscript.

Please correct the spelling of "MODIS-Aqua" consistently throughout the MS.

Response: The spelling of "*MODIS-Aqua*" has been consistently corrected throughout the manuscript.

SPECIFIC COMMENTS (line numbers are referenced)

51: the availability of PAR.

Response: We revised the sentence following the reviewer's suggestion:

lines 58-60: However, this shelf mixing can also inhibit phytoplankton growth by promoting resuspended sediments, which reduces the photosynthetically available radiation (PAR) (Byun et al., 2007; Xing et al., 2021; Kossack et al., 2023)

53: Define interfacial ITs.

Response: Following the reviewer's suggestion, we have added a definition of interfacial ITs:

lines 38-39: According to da Silva et al. (2002), as interfacial ITs propagate (i.e., IT waves that propagate horizontally along density interfaces) [...]

55: Use deep or subsurface chlorophyll maximum

Response: As suggested by the reviewer, we revised the term from "*depth of the chlorophyll maximum (DCM)*" to "*deep chlorophyll maximum (DCM)*".

61-62: "to two combined effects"

Response: We have corrected the sentence according to the reviewer suggestion:

lines 50-52: M'hamdi et al. (2025) demonstrated using a Slocum G2 glider deployed off the Amazon shelf during AMAZOMIX 2021 cruise that the enhancement of the CHL concentration associated with the passage of ITs may be due to two combined effects:

72: Indonesian Seas (there are several of them) or Indonesian Throughflow

Response: We agree with the reviewer's comment and have replaced the term "*Indonesian Sea*s" with "*the region of the Indonesian Throughflow*".

117: Suggestion: more than 20% of the time series.

Response: According to the reviewer's suggestion, we have replaced "*more than 20% in our time series*" with "*more than 20% of the time series*".

129: Define what is a showcase day.

Response: We have defined in the manuscript "showcase day" as follows:

lines 118-119: [...] CHL concentration on the day when ISW signatures were found (i.e., the specific day of the illustrative case) [...]

163: Is this assumption valid for this region? The freshwater inflow could have drastic effects on local stratification, likely preventing gradual and continuous profiles. How might this assumption affect your analysis? You should demonstrate the validity of your assumption specially because you are looking into a surface signature of these waves.

Response: We appreciate the reviewer's comment. We agree that freshwater input can strongly affect vertical stratification in the Amazon plume region. However, our study area lies south of the main extent of the plume, where the observed wave-like pattern occurs within approximately 400 km from the internal tide generation sites. In this region, the variability in stratification (N) is mainly driven by the regional current regime and mesoscale instabilities, such as eddies, rather than by freshwater inflow. Nevertheless, acknowledging that N may not vary gradually along the propagation pathways, we decided to remove the ray tracing experiments from the revised version of the manuscript.

173: N (or M – the lateral buoyancy gradient) will certainly exhibit lateral variability due to riverine input and submesoscale/mesoscale stirring.

Response: We appreciate the reviewer's comment. As discussed in the response to the previous comment, we acknowledge that N may not vary gradually along the propagation pathways due to lateral variability induced by mesoscale/submesoscale processes. Considering this limitation, we decided to remove the ray tracing experiments from the revised manuscript.

Figure 2: Points A and B are barely visible. The magenta font over red/orange background lacks contrast. Also, clarify which quantity is shown in panel D? In addition, having the coastline would improve visualization, orientation and highlight the relevant features. ISW signatures do not stand out, significant zooming is needed to see them.

Response: We have followed the reviewer's suggestion and improved the contrast at points A and D. A colorbar was added to panel D to clarify the quantities, and coastlines were included in the figures. We also made an effort to enhance the contrast of the ISW signatures. The revised figures are shown below.

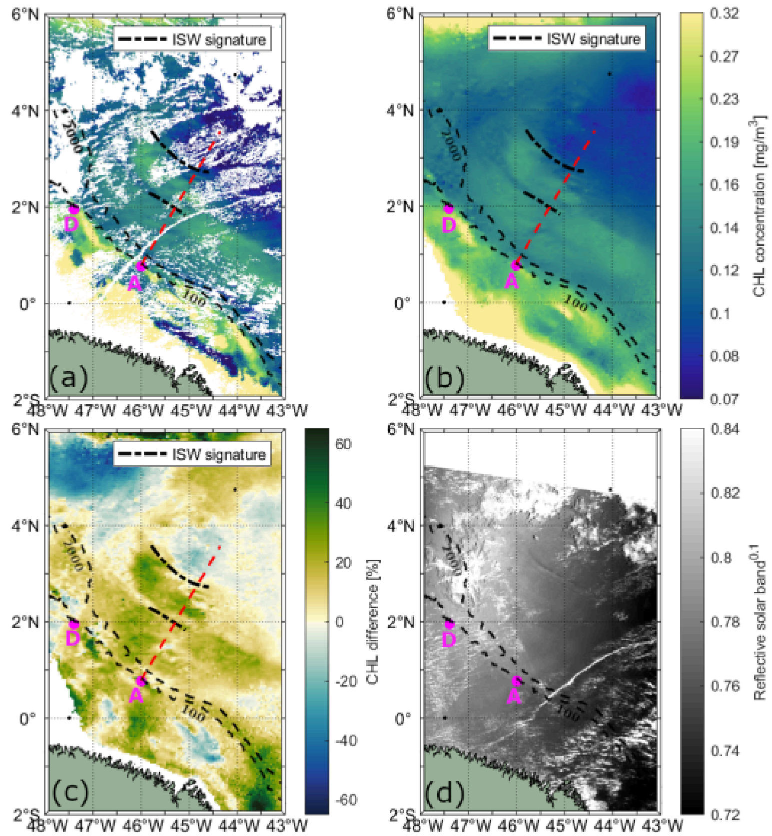

Figure 3. Illustrative case I showing the influence of ITs on CHL concentration on September 28, 2007. CHL concentration data is shown from (a) MODIS-Aqua and (b) Globcolour product. (c) CHL relative difference (%) between the CHL on the day of ISW occurrence and the 15-day mean CHL centered on that 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.

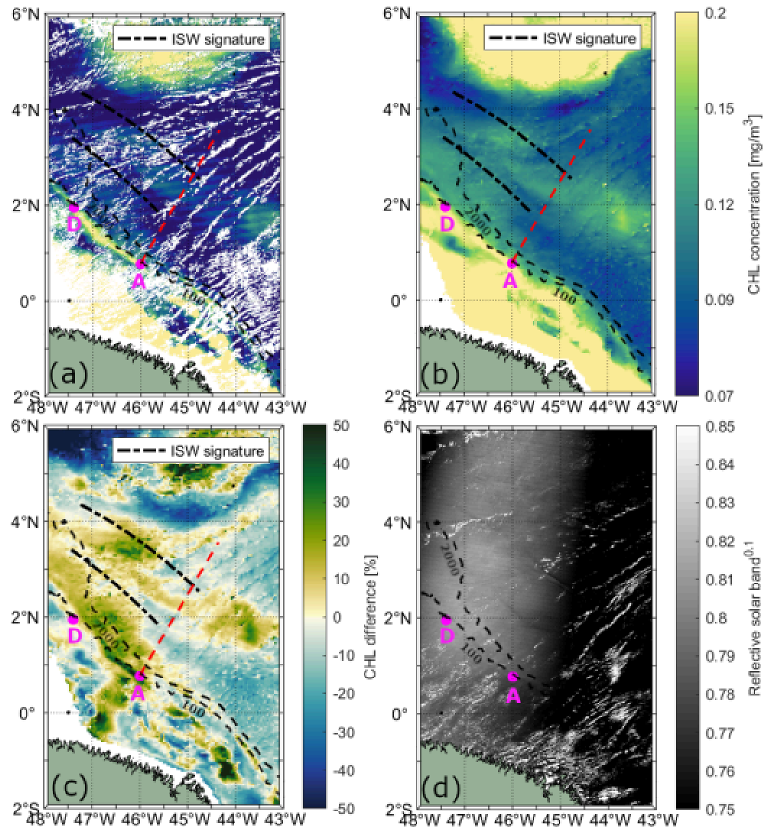

Figure 4. Illustrative case II showing the influence of ITs on CHL concentration on October 12, 2018. CHL concentration data is shown from (a) MODIS-Aqua and (b) Globcolour product. (c) CHL relative difference (%) between the CHL on the day of ISW occurrence and the 15-day mean CHL centered on that day (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.

189, 192: References for the typical wavelengths are needed.

Response: We added the reference for the typical mode-1 IT wavelength, as suggested by the reviewer. The revised text is shown below:

lines 182:183 The bands are separated by approximately 100 km, typical mode-1 IT wavelengths (150-100 km).

205: Clarify whether the average is temporal only (one value) or also considers spatial differences (2D map).

Response: As suggested by the reviewer, we have clarified in the text that the average refers exclusively to the temporal dimension. Specifically, we have established the link between the maps of CHL relative difference and Equation 1 as follows:

The maps of CHL relative difference (see Equation 1) are shown for illustrative cases I and II in Figures 2(c) and 3(c), respectively.

In addition, we have rewritten Equation 1 to make it explicit that only temporal differences are considered, and not spatial ones. The revised text now reads:

lines 116-125: The presence of ISW signatures in two MODIS-Terra images acquired under conditions of sunglint over the BEM is used as a proxy for IT activity. To emphasize the impact of ITs on the CHL concentration, We calculated the CHL relative difference at pixel p (in %), $\triangle CHL_p$*, defined as the deviation between the CHL concentration on the day when ISW signatures were detected (i.e., the illustrative case day) and the 15-day mean CHL values centered on that day:*

$$\Delta CHL_p(\%) = \frac{CHL_{p,0} - \overline{CHL_p}}{\overline{CHL_p}} \times 100 \quad (1),$$

where

$$\overline{CHL_p} = \frac{1}{15}\sum_{i=-7}^{+7} CHL_{p,i} \quad (2)$$

$CHL_{p,i}$ *is the CHL concentration at pixel p on day i (with i=0 the illustrative case day, i=−7 the 7th day before, and i=+7 the 7th day after). This enables the assessment of potential changes in CHL concentrations driven by ITs, compared to the CHL 15-day average within the study area.*

Figure 4: Consider adding arrows to highlight peaks.

Response: As suggested by the reviewer, we added arrows to highlight the peaks in the figure. The figure was originally numbered as Figure 4, but since an additional figure was included in the revised manuscript, it now corresponds to Figure 5. Please see the updated figure below.

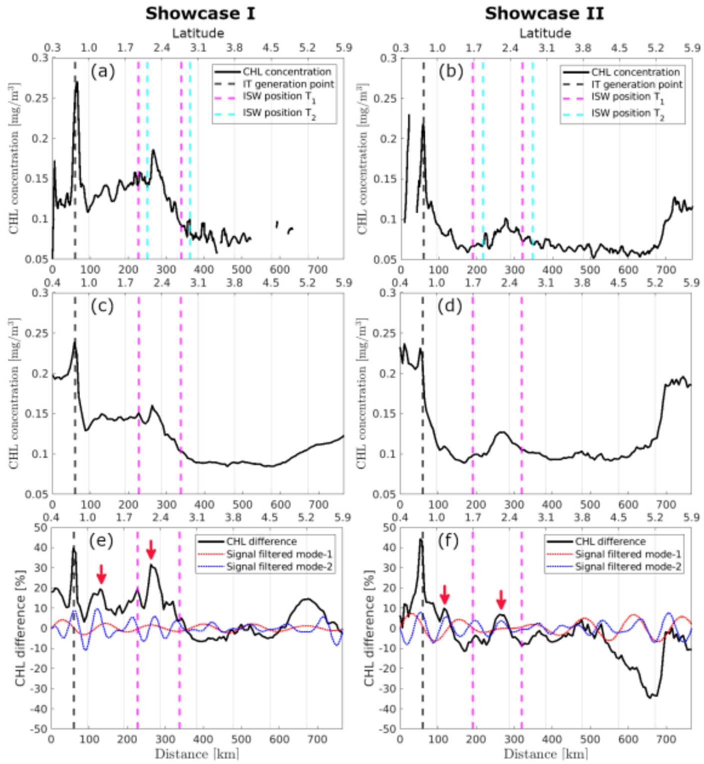

Figure 5. CHL concentration data along IT pathway A is shown from MODIS-Aqua for illustrative cases (a) I and (b) II, and from the GlobColour product for illustrative cases (c) I and (d) II. CHL relative difference is presented for illustrative cases (e) I and (f) II.

216: statistically significant.

Response: The term "*statistically significantly*" was revised to "*statistically significant*", as suggested by the reviewer.

249: Difference relative to what? Please clarify.

Response: As pointed out by the reviewer, we have clarified the sentence as follows:

lines 247-248: The positive peaks of CHL differences during the spring–neap tidal cycle, with a 1-day delay, average around 2.1% across all IT pathways.

337-341: Here and later on. How would the DCM be visible from remote sensing? Does IT-induced mixing bring chlorophyll from the DCM to the surface?

Response: The light penetration depth determines how deep remote sensing instruments can "see" into the water column. When interfacial ITs propagate, some studies have shown that they can modulate the DCM by displacing it above or below this depth (da Silva et al., 2002; Muacho et al., 2014; Kim et al., 2018; M'Hamdi et al., 2025). Such vertical displacements may result in either enhanced or reduced chlorophyll-a concentrations detectable by remote sensing. Additionally, as shown by M'Hamdi et al. (2025) mixing events associated with ITs increase

CHL concentration in both the surface and bottom layers of the water column. This concept is further discussed in the Introduction section:

lines 38-44: According to da Silva et al. (2002), as interfacial ITs propagate, they cause vertical displacements in the pycnocline and hence displace passive phytoplankton cells within the water column. This movement shifts the deep chlorophyll maximum (DCM) either above or below the light penetration depth, resulting in, respectively, increased or decreased chlorophyll-a concentrations (hereinafter referred to as CHL) detected by remote sensing (da Silva et al., 2002; Muacho et al., 2014; Kim et al., 2018; M'Hamdi et al., 2025).

Additionally, ITs enhance the vertical mixing of nutrients into the DCM, thus supporting primary production (Sharples et al., 2007; Tuerena et al., 2019; Kossack et al., 2023; Jacobsen et al., 2023). Jacobsen et al. (2023) studied the response of primary production to IT beams based on model simulations configured for an oligotrophic system with a nutricline depth below 50 meters. They found that while subsurface light limitation is reduced for passive plankton within tidal beams, leading to higher primary production rates, the dominant effect of tidal beams on primary production is the increased nutrient supply to the euphotic zone near tidal beam generation locations. M'Hamdi et al. (2025) demonstrated using a Slocum G2 glider deployed off the Amazon shelf during AMAZOMIX 2021 cruise that the enhancement of the CHL concentration associated with the passage of ITs may be due to two combined effects: 1) the ITs modulate the DCM, causing its vertical displacement and oscillation as it rises and deepens in response to IT propagation. This movement may enhance phytoplankton's light exposure, stimulating primary production; 2) Mixing events associated with ITs increase CHL concentration in both the surface and bottom layers of the water column.

To clarify this concept in the specific part of the manuscript mentioned by the reviewer, we have rewritten it as follows:

1) Tidal aliasing combined with the modulation of the DCM induced by the passage of interfacial IT waves. Interfacial IT waves can bring DCM above the light penetration depth, allowing the remote sensing instrument to observe it. Regarding tidal aliasing, this implies that MODIS-Aqua consistently captures IT crests in nearly the same location, since both IT generation and the satellite orbit are synchronized with the M2 tidal constituent.

379: The MS focuses on internal tide signatures in surface chlorophyll; clarify why barotropic tides are also discussed.

Response: Since our manuscript was primarily focused on exploiting the fortnightly signal in remote sensing surface chlorophyll concentration, some patterns associated with barotropic tides also emerged. We considered it relevant to include a discussion on this topic, as barotropic tides are directly linked to the generation of internal tides. We appreciate the reviewer's comment, and in response, we have revised several sections of the manuscript (including the title, abstract, and conclusion) to broaden its scope and explicitly address the role of barotropic tides in addition to internal tide signatures.

386-389: These statements are speculative. Explain more clearly how the time series analysis supports these conclusions.

Response: We agree with the reviewer, and all the speculative parts have been removed from the conclusions. It was retained only in the discussion section, where its speculative nature is explicitly highlighted.

389: Clarify "lower turbid"?

Response: We made a grammatical mistake and have corrected the term from "lower turbid" to "less turbid" in the manuscript. Thank you for pointing this out.

392-393: "as they propagate offshore the open ocean", likely a typo; please check.

Response: we corrected the sentence "*as they propagate offshore the open ocean*" to "*while they propagate offshore*".

402: […] beam signal is attenuated after 300-400 km […]

Response: According to the reviewer's suggestion, we revised the sentence as follows:

lines 402-403: The beam signal in the GlobColour and MODIS-Aqua composites becomes attenuated after 300–400 km.

404: more effective TO OBSERVE.

Response: As suggested, the term "for observing" was replaced with "to observe."

417: How is stratification a "background circulation feature"?

Response: We agree with the reviewer that stratification should not be considered a "background feature." Therefore, we have removed this statement from the manuscript.

421-422: This statement is clearer than Lines 386-389.

Response: In accordance with the reviewer's suggestion, we have removed the statement that was originally included between lines 386 and 389.

423-424: Could the difference between tracers simply be because chlorophyll is biologically reactive while temperature is a physical tracer? The current explanation is overly complicated. I do not agree with your argument.

Response: We appreciate the reviewer's insightful comment. We agree that the difference between tracers may also be related to their distinct nature, with chlorophyll being biologically reactive while temperature is a physical tracer. However, a detailed investigation of this question lies beyond the scope of the present study. To avoid an overly speculative explanation, we decided to remove our initial interpretation and instead cite Assene (2024), who reported that IT propagation induces a surface cooling of approximately –0.2 °C. This study also highlights that ITs enhance the net heat flux at the air–sea interface, which tends to dampen the IT-induced SST cooling.

We have removed this from the Conclusion and revised the corresponding part of the Discussion section as follows:

lines 292-298: The fortnightly signal in SST is weaker than that observed in CHL and becomes even less pronounced offshore. Using two regional simulations (with and without tides), Assene (2024) estimated sea temperature anomalies along IT pathway A and reported offshore surface anomalies of approximately –0.2 °C. The study also showed that ITs modulate upper ocean–atmosphere interactions by enhancing the net heat flux at the air–sea interface. This enhanced flux from the atmosphere to the ocean tends to damp the IT-induced SST cooling and contributes to restoring surface temperatures (Assene, 2024). Such restoration could explain the weaker fortnightly signal in SST compared to CHL. Nevertheless, further studies are needed to understand these differences better.

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

REFERENCE

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