Spatial and temporal variability of mode-1 and mode-2 internal solitary waves from MODIS/TERRA sun glint off the Amazon shelf.

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We thank the reviewer for taking the time to review our manuscript and especially for the valuable comments regarding the impact of the background current in the mode-2 waves according to the seasons, the use of the kdv, and the valuable new reference. In the following, our responses to the reviewer's comments are in bold black colors.

The paper is focused on the characterization of ISWs off the Amazon shelf from MODIS satellite imagery. The most important result is the characterization of recurrent mode 2 ISWs and the impact of seasonality/circulation on wavelength and phase speed propagation directions. Regarding mode-1 ISWs most of the results confirm the analysis of Margalhães et al (2016) based on SAR data; more interesting is the detection of mode-2 ISWs which are more impacted by seasonality and circulation than mode-1 waves.

I believe the paper could be accepted for publication after moderate/minor revisions.

In general, the analysis is convincing. I think yet that the background conditions obtained from the model for the circulation and IT generation could be added to further evidence the impact of circulation on the figures. I also think that a ray tracing computation for mode-1 and mode-2 following Rainville 2006 would be a nice addition to further illustrate the impact of refraction by the circulation.

ANSWER:

New calculations of the time-space variability of the waves' phase velocity in the study area were used as a proxy for change in the wave's propagation velocity (refraction). This methodology was chosen because seemed to be the more direct way to take into account the effects of both background circulation and stratification through the TGE. In fact, results show higher variability of phase velocity for mode-2 waves than mode-1, showing mode-2 waves as more sensitive to the background condition, as suggested by our measurements and the findings in Rainville and Pinkel (2006). Furthermore, in area 2, higher variability aligned to the NECC was found during ASOND, in good agreement with our results. Indeed, the authors agree that in the future the ray tracing computations for mode-1 and mode-2 ISWs would be a great addition for further understanding the waves in our study region, especially considering the very different background current conditions according to the seasons. For more details, please, see pages 18-19, lines 286-294, and Figure 15.

Another point is that I do not really agree with the fact that the authors rule out KdV arguing it does only apply for flat bottom, it is also the case for their modal decomposition! I believe some KdV estimate of the phase speed would probably mostly fill the gap between the phase speed they observe from satellite and the linear modal phase speed. The problem is more than they can't estimate the amplitude of the ISWs to get the Kdv phase speed. All in all despite the systematic underestimation of phase speed/wavelength by the linear model, the difference of characteristics between mode-1 and mode-2 and the bimodal distribution of ISWs characteristics is enough to convince the reader that both ISW mode-1 and mode-2 are observed.

ANSWER

Considering that, in the study area, the upper layer thickness (h_1) is smaller than the lower layer (h_2) (see Figure 1, where a representative profile of density in the study area is shown based on the climatology EPR data), the wave interface displacement will be a depression. So, the nonlinear phase speed (c), following the KdV equation, can be calculated as follow (Jeans, 1995):

$$c = c_0\left(1 - \frac{\alpha\eta_0}{3c_0}\right)$$

where η_0 being the maximum wave elevation, and α being the nonlinear coefficient:

$$\alpha = -\frac{3c_0\,(1+r)}{2h_1}$$

and $r = h_1/h_2$.

This means that a nonlinear component directly proportional to the wave elevation should be added to the linear phase speed of the waves. Taking from Figure 2, $h_1 \sim 100$ m and $h_1 \sim 3800$ m, and considering $\eta_0 = 100$ m (Brandt, 2002), and $c_0 = 2.16\ m.s^{-1}$ for mode-1 waves (considering a two-layer model Gill, A. E. (1982). *Atmosphere-ocean dynamics* (Vol. 30). Academic press.), the nonlinear component is about 1.26 $m.s^{-1}$, i.e., $c = 3.42\ m.s^{-1}$. This value is about 16% overestimated compared to our remote sensing measurements (mean mode-1 velocity in area 2 of 2.94 $m.s^{-1}$) and also to values presented by Magalhães et al. 2016 (who find a mean mode-1 velocity of 3.1 $m.s^{-1}$). This information was added to the text, please, see page 25, lines 439-440.

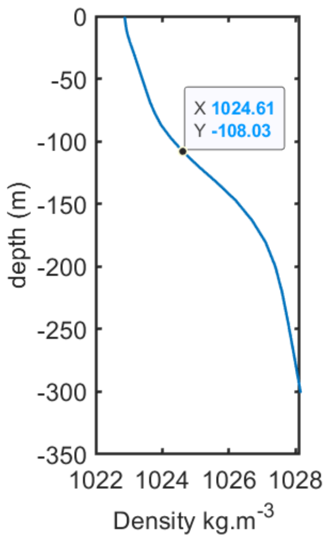

Figure 1 - Representative profile of Density in Amazon shelf from climatology EPR data.

In the abstract and the conclusion, the authors suggest at generation of ISW at the point of IT beam reflection, I guess this corresponds to the local generation mechanism described by Gerkema, if so he should be cited and this mechanism more thoroughly discussed.

ANSWER:

The bibliography "Gerkema, T. (2001). Internal and interfacial tides: beam scattering and local generation of solitary waves. Journal of Marine Research, 59(2), 227-255"

was added to the manuscript. The mechanism was thoroughly discussed based on that bibliography (please, see Page 20, lines 305-307).

The abstract refers to very specific labels/features of the figure and is mostly impossible to understand without seeing the figure. Although it is fine to put some quantitative results in the abstract I would suggest to delete too much specific reference to fig labels etc…

ANSWER:

Specific labels/features were removed from the abstract as suggested by the reviewer.

I have several more specific comments/questions below.

1. Abstract L14-15 seems contradictory with previous sentence.

ANSWER:

We have changed the text to be more comprehensive: "The mean mode-1 and mode-2 propagation velocities/wavelengths do not show significant differences according to their IT generation sites. A larger proportion of mode-2 waves is likely linked to shallower pycnocline with higher maximum values" (Page 1, lines 10-12).

2. L61 shift what? the depth of max amplitude of displacement i-e velocity node?

ANSWER:

Deeper pycnocline shift the first extrema of the vertical modal structure to deeper water layers and the second one to shallower layers. This information is added in the text as follows: "Analyzing the vertical modal structure for mode-2 IT, a deeper pycnocline seems to shift the extrema of the modes toward intermediate water layers (i.e., the first extremum is deeper and the second one is shallower" (see Page 3, lines 56-57).

3. L146-147 how these diffusivities and viscosities are estimated, what is their impact on the phase speed?

ANSWER:

The original T-G equation was solved assuming inviscid flow. Lian's numerical method, which was used in our paper, is indeed for the viscous Taylor-Goldstein equation. The method includes the effects of viscosity and diffusivity, which in origin

we choose to be the kinematic viscosity of water at 20 °C, i.e., 1 cSt or $10^{-6}\ m/s^2$ and the thermal diffusivity of water at 20 °C, i.e., 1.43$.10^{-7}\ m/s^2$ (this information is added in the manuscript, please, see page 25, lines 430-434). We have done tests and for internal tidal waves (of various modes) it does not make any difference to use one or another.

4. L187 On figure 2 A and B are between isobath 500 and 2000 m not 200 m.

ANSWER:
Indeed, the Isobath's legend was messed up. We corrected it in the Figures and in the text (please, see Page 7, lines 156-157).

5. L194-195 cloud cover could definitely be as strong biased isn't it possible to get the distribution for clear sky images, or even simply the mean crest length and stdv for clear sky images?

ANSWER:
Indeed, cloud cover image distribution over a year may induce some bias on the crest length statistics, underestimating its actual arc length. Working with optical/passive imagery systems such as MODIS is the price to pay. On the other hand, MODIS-Terra statistics can be complementary to the SAR-derived one, as its spatial and temporal coverage are usually superior. Moreover, MODIS-derived data allows extracting other essential statistics such as the number of waves in a packet, inter and intra-packet distances.

6. L202 why normalized?

ANSWER:
More signatures during the months of ASOND, for example, could be only a reflection of the higher number of images with less cloudy coverage. So, we have done the normalization (number of detected signatures according to the different wave modes divided by the total number of images containing at least one clear signature) to attenuate the impact of cloud coverage seasonability.

7. L203-205 It seems really difficult to conclude anything on the seasonality of the number of signatures, if we restrict to months with at least 5-10 images I don't see any significant differences.

ANSWER

The authors agree with the reviewer and we have changed this in the manuscript: "Because of the lack of acquisitions for some months, no evident seasonal variability is found" (please, see pages 7-8, lines 172-173).

8. L209 I don't get this sentence, you find mode 1 every year according to Fig4 b and mode 2 every year except 2009, what do you mean by "the annual probability of finding a mode-1 signature is more than 4 times the probability of finding a mode-2 one".

ANSWER:

The analysis was redone and the phrase was changed to: "The total number of detected mode-1 waves is about 3 times the number of mode-2 ones" (please, see Figure 4, and page 8, lines 174-175).

9. Paragraph starting at L219 seems to me to describe the method to separate mode 1 and mode 2 wave and should therefore be introduced before Fig.5.

ANSWER:

This paragraph was shifted before Figure 5, as suggested by the reviewer.

10. L284 how do you define near spring? +/- 7 days after peak spring?

ANSWER:

Yes, near spring tide is defined as +/- 7 days after spring tide peak. This information was added in the manuscript: "Near spring tide is defined as +/- 7 days after spring tide peak" (please, see Page 13, line 230).

11. L296-297 difference of phase speed between spring and neap tide is typically a result of amplitude/nonlinearity so it can't be reproduced.

ANSWER:

The authors agree with the reviewer's comment and this part was removed from the manuscript.

12. L363 I think the authors describe the generation of ISW at the point of IT beam reflection, I guess this corresponds to the local generation mechanism described by Gerkema, if so he should be cited I think.

ANSWER:

The bibliography "Gerkema, T. (2001). Internal and interfacial tides: beam scattering and local generation of solitary waves. Journal of Marine Research, 59(2), 227-255" was added to the manuscript (please, see Page 20, lines 305-307).