Seasonal estimations of baroclinic tides using MIOST model and altimeter data

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Abstract

Internal tides (IT) have a sea surface height signature of several cm with wavelengths about 50-250 km for the first mode and even smaller for higher modes. In the perspective of high-resolution ocean missions, the correction of these small-scale signals is mandatory, as we need to separate all tidal variability from other oceanic signals. Several scientific teams have developed some empirical and hydrodynamic IT models in order to correct the coherent IT signal for the main tidal components (M2, K1, O1 and S2; Carrere et al. 2021). Using these models allows a significant altimeter variance reduction on ocean regions where IT are generating and propagating, and Zaron model (2019) is now used in altimetry GDRs. However non-stationary IT signal due to seasonal variability of the ocean conditions and the interactions with mesoscales and other ocean waves is still not corrected as it is more difficult to estimate.

Seasonal estimations of the surface IT signal have been performed using the MIOST model (Ubelmann et al. 2021), theoretical estimations of seasonal IT parameters (S. Barbot personal communication) and the nearly entire altimeter database available (1993-2020). Analysis has been conducted on three different regions with different oceanic behaviors. We present the regional models and their impact in terms of altimeter variance reduction on the Amazonia and the Indonesian seas areas.

1-Description of models and methodology for analysis

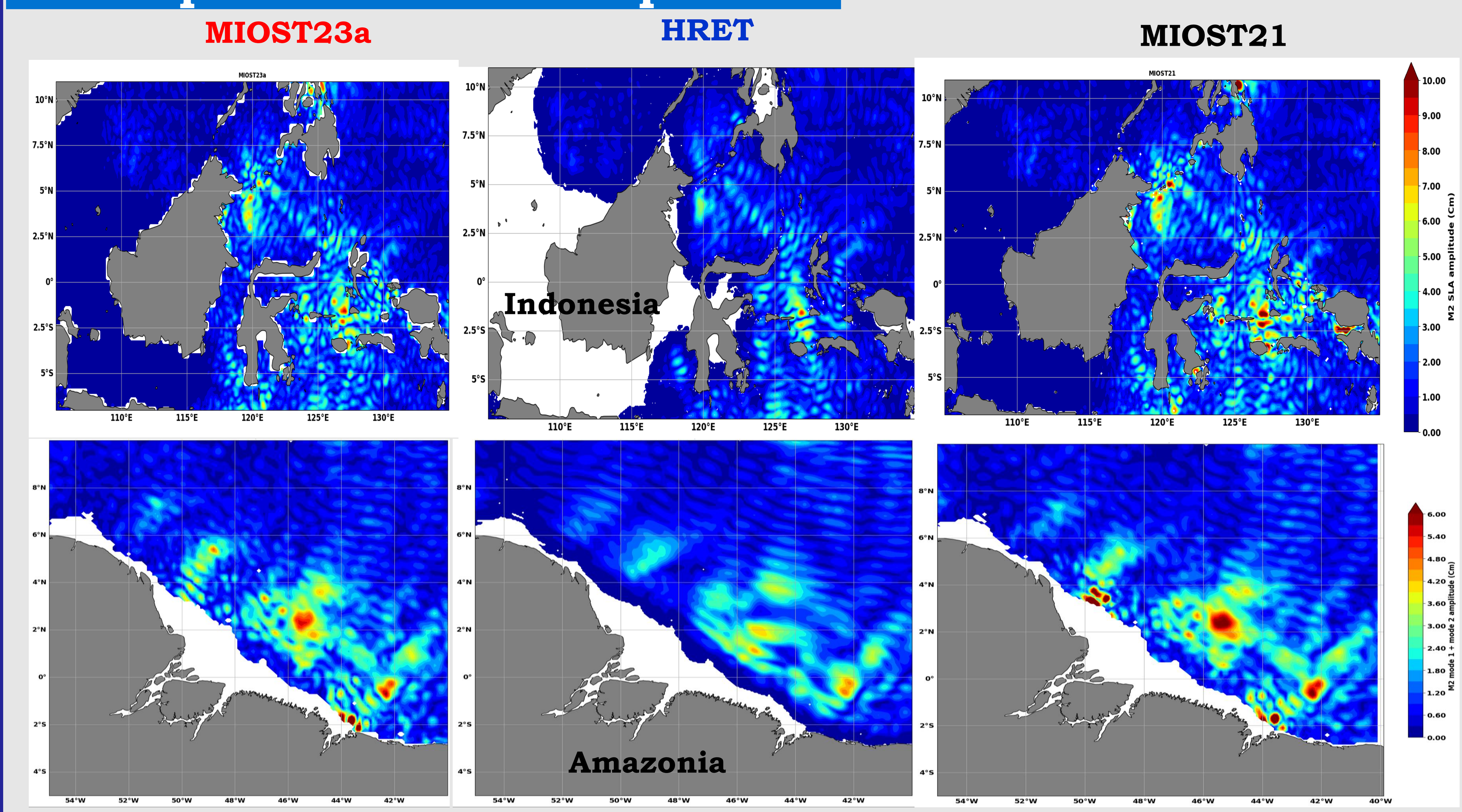
Tab1: Comparison of empirical IT models: HRET vs MIOST

	HRET (Zaron et al., 2019)	MIOST (MIOST21 and MIOST23)
Altimeter data	TP-J1-J2+ERS-EN-AL+GFO	All except C2
Analysed period	1992-2017	1993-2017
Mesoscales	Prior removing from AVISO/DUACS MSLA	Simultaneous estimate with IT in a single inversion
IT dispersion relation	No	Yes (need phase speed and IT frequency)
Harmonical Analysis	Yes	No (forcing frequency within the IT dispersion relation)

What's the difference between the two MIOST versions?

- **MIOST21 (Ubelmann et al. 2021)**: The phase speed of mode 1 is deduced from the climatology of the first Rossby radius of deformation of Chelton et al. (1998). The phase speed of mode 2 is half that of mode 1. See Ubelmann et al. 2021 for more details. MIOST21 is available on the AVISO website.
- MIOST23: Phase speed for modes 1 and 2 are theoretically estimated by vertical mode analysis, for which density profiles from the GREP atlas (1993-2018; data available here https://doi.org/10.48670/moi-00023) were prescribed (S. Barbot, personal communication).
- We have developed **MIOST23a** using the global mean density and **MIOST23m** for each month using the monthly mean densities.

2- Comparison of models' patterns



Tab2: Spatial mean (cm) and standard deviation (cm) of M2 SLA amplitude. **MIOST23a** in red color, **HRET** in blue color and **MIOST21** in black color

Area	Mean (cm)	Standard variation (cm)
Amazonia	**1.11 | 0.90 | 1.05**	**0.97 |0.73 |0.89**
Indonesia	**1.36 | 0.86 | 1.27**	**1.29 |0.86 |1.12**

- ✓ MIOST gives access to certain areas masked in HRET.
- ✓ IT amplitude is stronger and varies more spatially in MIOST23 than in HRET.
- ✓ Some amplitudes of mode 2 in MIOST21 are attenuated in MIOST23.

Fig1: M2 SLA amplitude (over 1993-2017) from different IT models : MIOST23a (left), HRET (middle) and MIOST21 (right). Mean density profiles are used for MIOST.

3- Seasonal analysis

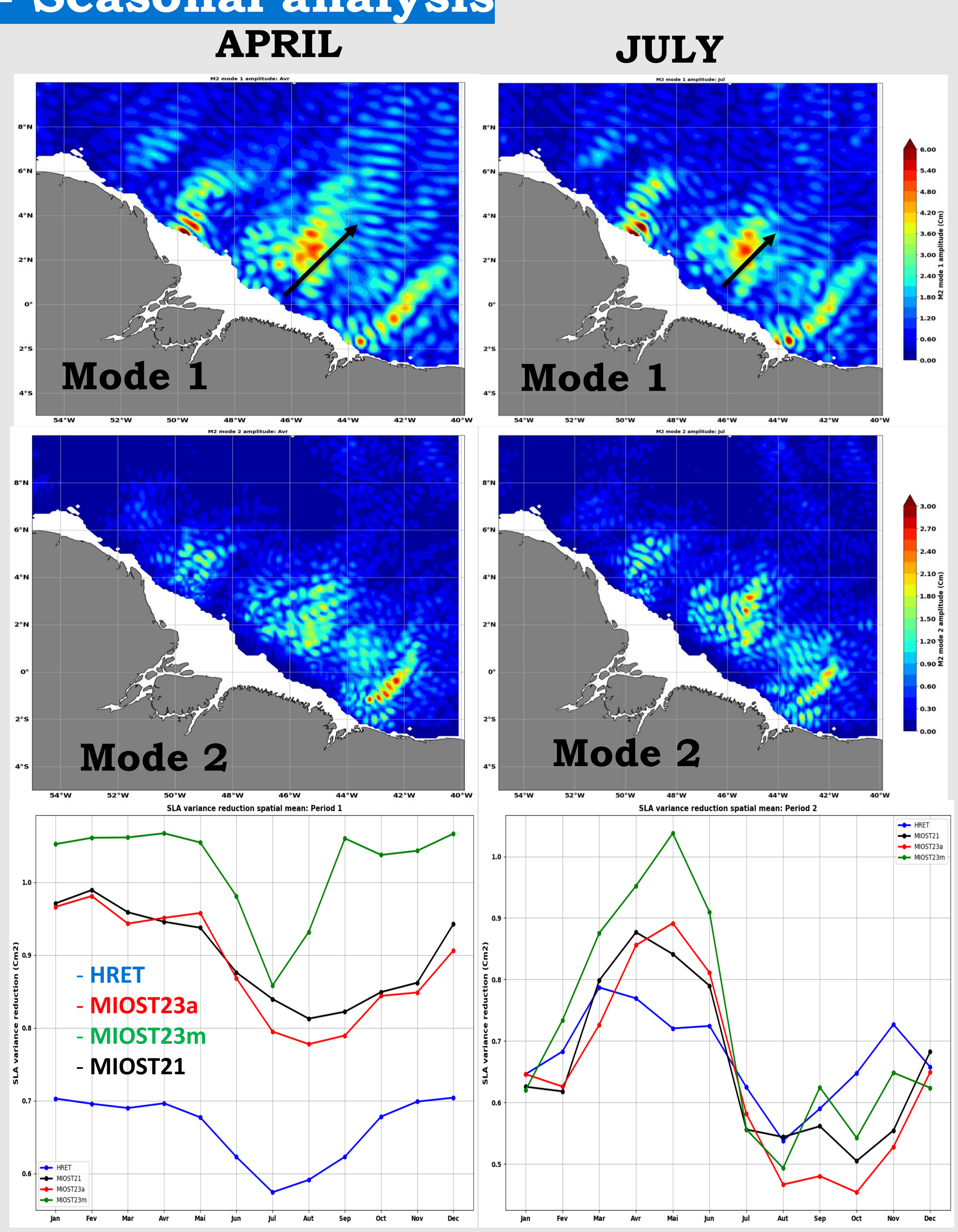


Fig2: Top and Middle: Mode 1 (top) and mode 2 (Middle) M2 SLA amplitude from MIOST23 in Amazonia for April (left) and July (right) during period 1. Bottom: Seasonal cycle of the spatial mean of the SLA variance reduction in Amazonia for period 1 (left) and period 2 (right). MIOST23m (monthly) in green, **MIOST23a** (annual) in red, **MIOST21** (annual) in black and **HRET** (annual) in blue.

- ❑ MIOST23m monthly M2 model was built using monthly phase speed based on GREP monthly density profiles (S. Barbot, personal communication).
- ❑ To build the monthly IT model, we used altimetry data for the month in question and 15 days of observations from each of the two surrounding months.
- ❑ The altimeter data are divided into two periods: Period 1 (1993-2017) to build the model and Period 2 (2017-2020) for validation.
- ❑ In the Amazon region (Fig2), mode 1 IT propagates more towards the open ocean in April than in July. There is also evidence of a change in amplitude and distribution for mode 2.
- ❑ Mode 2 intensifies in June in the Indonesian region (Fig3).

Variance reduction = Var (SLA) – Var (SLA-M2 model)

1- Period 1: MIOST23m (monthly) reduces variance more than other models on both regions. The performance of the MIOST23a (annual) model is equal to or better than that of MIOST21.

2- Period 2: In Amazonia, the MIOST23m model performs better when IT is more coherent (first half of the year). In Indonesia, MIOST23a reduces the variance more than the other models, certainly due to strong IT incoherence during the year in this area.

3- For both periods, MIOST23 has the best performance.

4-The low amplitude of HRET makes it the least efficient of the three models, although they perform similarly over July-Dec in Amazonia for period 2.

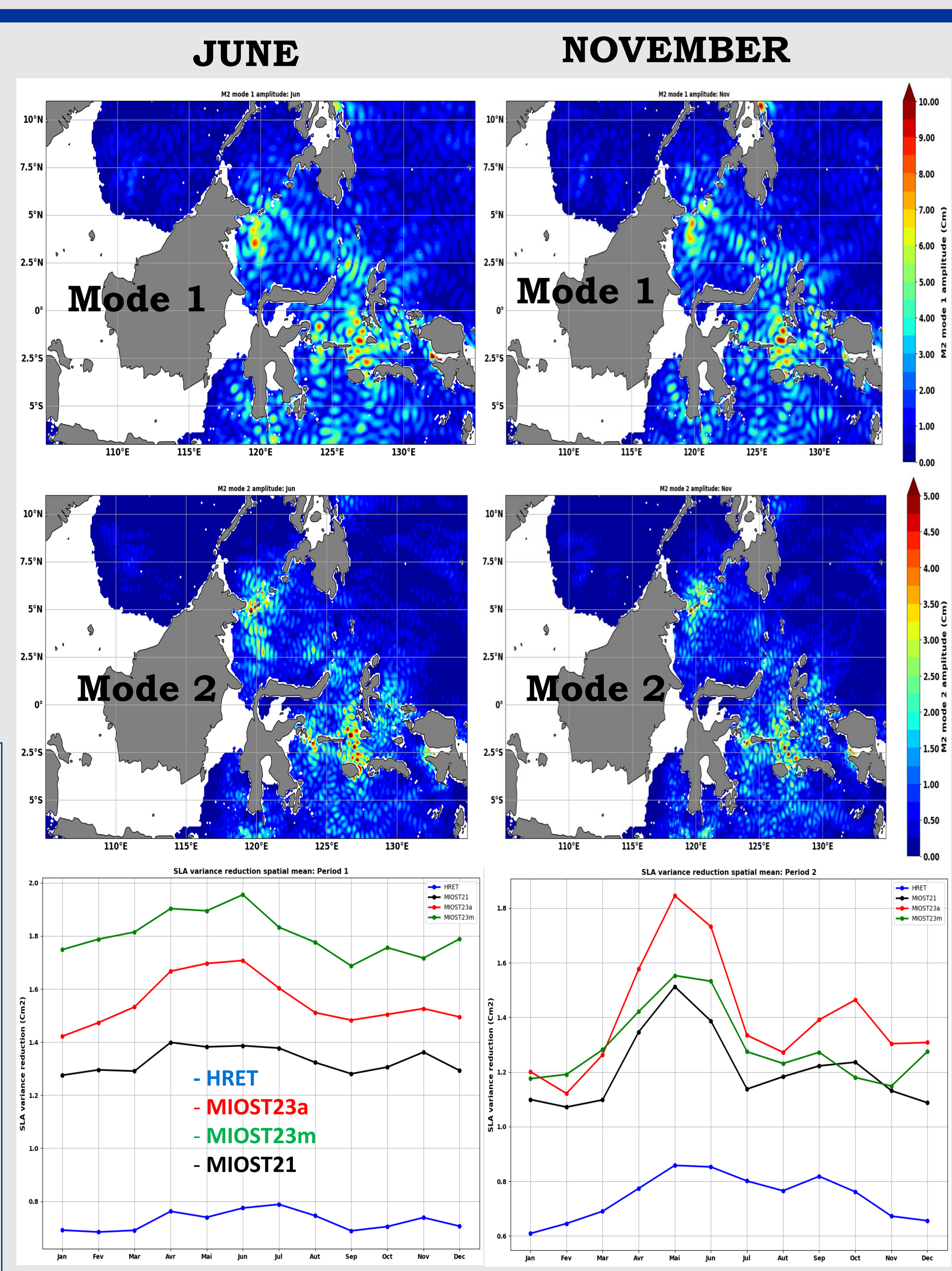


Fig3: Same as Fig2 for Indonesia region.

Conclusion and perspectives

We have implemented a new version of MIOST using the theoretical phase speed based on the GREP density atlas. This new version outperforms existing models (MIOST21 and HRET) in Amazonia and Indonesia. The altimetry data clearly show the seasonal (monthly) variability of IT mode 1 and mode 2 in those regions, with complex features. We plan to extend the study to other ocean areas and produce a new global annual and monthly internal tides atlas.

Some tests should also be performed in the coming months using the new SWOT 1 day data in addition to other nadir altimeters dataset to try to improve the spatial mapping of the IT and also tackle the non coherent part of IT.