Use of new baroclinic tide models to improve the correction of internal tides in SWOT data

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Introduction

The Surface Water and Ocean Topography (SWOT) altimetry mission launched at the end of 2022 is an opportunity to access ocean variability at a scale extending to 15-30 km, and to better understand ocean dynamic. To properly analyze mesoscale, sub-mesoscale, and large-scale dynamics from SWOT data, it is necessary—just as for other altimetric missions—to correct for the high-frequency signal associated with internal tides (IT). This work aims to assess three newly developed global IT models: atlases **MIOST-IT24** (Multivariate Inversion of Ocean Surface Topography -IT24,Tchilibou et al., 2025), **HRET22** (High-Resolution Empirical tide 22; Zaron and Elipot 2024), and **Zhao30yr** (Zhao 2025) in terms of their ability to remove stationary IT variability from SWOT nadir measurements.

1-Description of IT models

The atlases **HRET**, **MIOST-IT**, and **Zhao** belong to the class of so-called *empirical IT atlases. They* are derived from the analysis of multi-year altimetric sea level anomaly (SLA) observations. **HRET22** is the reference atlas used in SWOT products. It is constructed as a combination of **HRET8.1 (Zaron 2019)** and **HRET14 (Zaron and Elipot, 2024)**, both obtained through a methodology that includes harmonic and spectral analyses. **MIOST-IT24** represents an evolution of **MIOST-IT22 (Ubelmann et al.,2022).** It is built from a single inversion approach that directly separates internal tides from mesoscale variability. Finally, **Zhao30yr** is derived from 30 years of observations using a two-step plane-wave analysis technique and a spatial band-pass filtering stage between the two rounds of plane-wave fitting. Table 1 provides a comparative summary of the main characteristics of the three models, whereas Figure 1 illustrates the set of altimetric missions used in the derivation of atlases MIOST-IT24 and Zhao30yr.

Tab1: Comparison of HRET22, MIOST-IT24 and Zhao30yr IT models

	HRET22	MIOST-IT24	Zhao30yr
Origin	Merge of HRET8.1 and HRET14	Direct analysis of the altimetric measurements (see Fig. 1)	Direct analysis of the altimetric measurements (see Fig.1)
Analysed period	1992-2021	1993-2022	1993-2022
Mesoscales	Prior mesoscale correction using 2D gridded SLA.	Simultaneous estimate in a single inversion.	Prior mesoscale correction using 2D gridded SLA.
Stratification profiles	Not required	Glorys12v1 (1993 – 2020)	World Ocean Atlas 2018
Mode 1 wavelengths	spectral analysis	vertical mode	vertical mode
Mode 2 wavelengths	spectral analysis	vertical mode	vertical mode
Tidal waves	M2,S2,N2,K1 and O1	M2,S2, K1 and O1	M2,S2,N2,K2,K1,O1,P1 and Q1

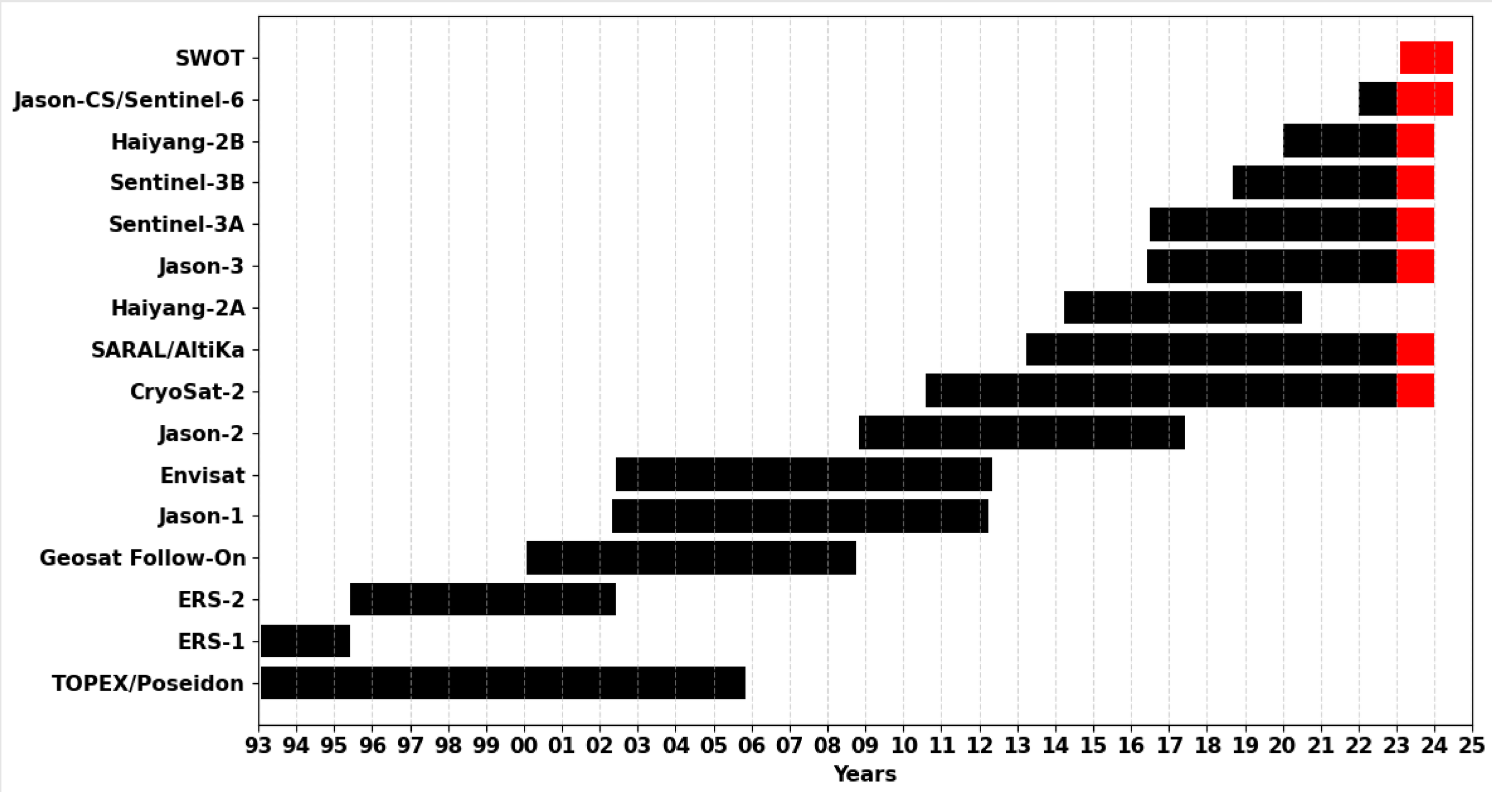

Fig1: Satellite altimetry data. In black, data used for MIOST-IT and Zhao30yr atlases construction; in red, data reserved for validation.

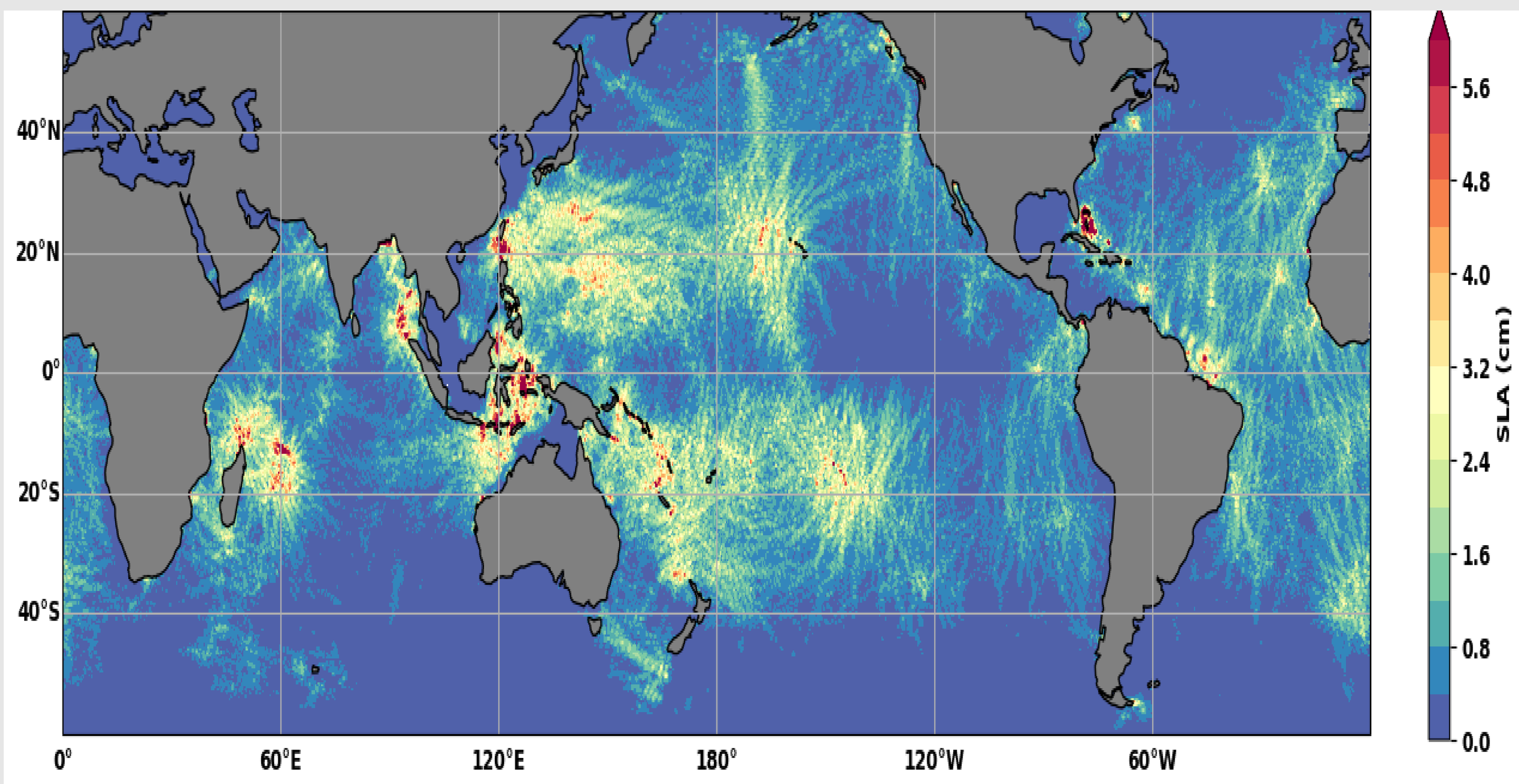

Fig2: M2 MIOST-IT24 amplitude (cm). The figure is the same for the three atlases. .

Figure 2 shows the M2 MIOST-IT24 atlas. This highlights the main areas of IT generation and their stationary trajectories. As with the other atlases (not shown), the amplitude of the M2 internal tide can exceed 5 cm.

2- Atlas Validation

The ability of the atlases to correct IT signals is assessed using 21-day SWOT-nadir data from the 2023–2024 period. The left panel of Figure 2 shows the difference in variance reduction between SLA corrected with MIOST-IT24 and SLA corrected with HRET22, computed as var(SLA – MIOST-IT24) – var(SLA – HRET22). Blue shading indicates regions where MIOST-IT24 provides a better correction of IT in SLA than HRET22. The right panel of Figure 3 presents the corresponding comparison between MIOST-IT24 and Zhao30yr, expressed as var(SLA – MIOST-IT24) – var(SLA – Zhao30yr). For comparison purposes, the SLA has been corrected for the four waves that are common to all three atlases: M2, S2, K1, and O1.

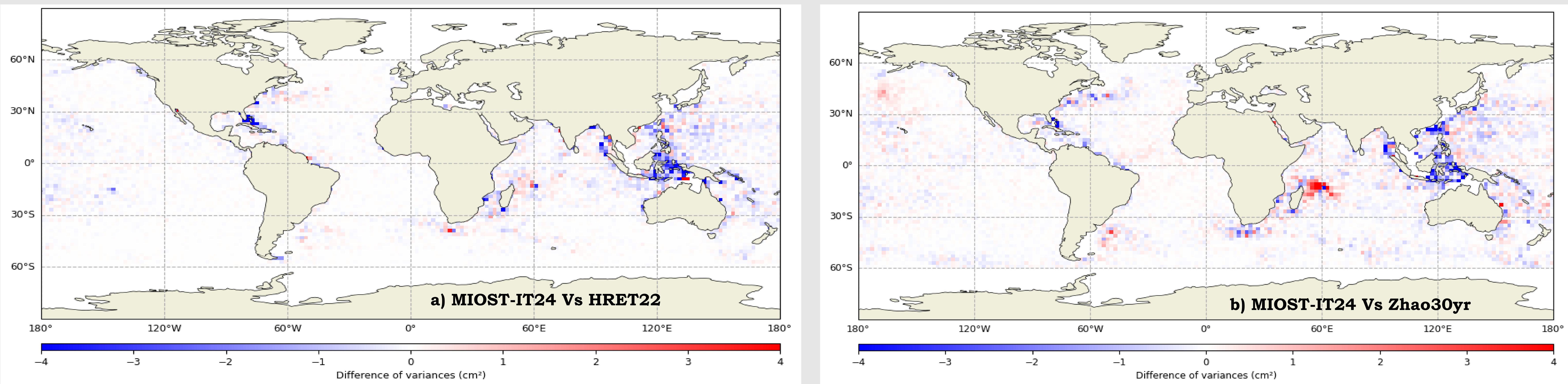

Fig3: Difference of variance reduction over 2023-2024 using 21-day SWOT-nadir data, a) var (SLA-MIOST-IT24) – var (SLA –HRET22). b) var (SLA-MIOST-IT24) – var (SLA - Zhao30yr). Units: cm²

- Overall, **MIOST-IT24** yields a slightly higher global variance reduction relative to the independent data than **HRET22** and **Zhao30yr**.
- **MIOST-IT24** shows particularly strong performance in the western tropical Pacific and Caribbean.
- in some regions like Aghulas, we observe better performances of **HRET22**,
- **MIOST-IT24** increases the variance in the regions north of Madagascar and Hawaii compared with **Zhao30yr**.

Conclusion and perspective

The performance of the three recent (HRET22, MIOST-IT24 and Zhao30yr) internal tide global atlases was tested using SWOT 21 days data from 2023 to 2024. The results show a slight advantage for MIOST-IT24, although it performs less well than Zhao30yr in some parts of the ocean. The conclusions remain the same when variance reductions are calculated using all the available altimetry data over this period (see Fig.1). The atlases improve the stationary IT corrections in altimetry data. However, the nonstationary part and the very small scales observed by SWOT remains a challenge to correct.

References:

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