Assessment of global and regional tidal models in coastal regions – a contribution to improve coastal altimetry retrievals

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Introduction

Because of the repeat period of the satellite altimetry missions, **the high-frequency ocean tidal signals are aliased in the altimeter sea surface height measurements at periods that correspond to other ocean dynamics processes**. To access the ocean circulation dynamics with the centimetric level of accuracy expected by the users, it is thus necessary to **accurately remove the ocean tide signals from the altimeter measurements.** To remove this signal, global tidal models such as GOT4.10 and FES2014b are used in official altimetry products provided by the space agencies. However, these models still show large errors on the continental shelves and in coastal regions, where tidal amplitudes range from several centimetres to several metres and are more complex to model due to non-linear interactions between the tidal waves and the shallow bathymetry. With new and future satellite altimetry techniques (SAR, wide-swath) that enable to reach ever more coastal areas, and to resolve the ocean dynamics at ever finer scales, the **need for accurate coastal tidal model solutions is salient**.

Today, specific efforts are made to improve the tidal models in the coastal regions, thanks to high-resolution modelling and to the use of coastal observations (from altimetry and tide gauges) to constrain the models. Various models are thus available, at global and regional scales. These models are generally not provided in the altimetry products, but they could be of high interest to locally improve the coastal altimetry sea surface height retrievals. In the frame of the HYDROCOASTAL project, funded by the European Space Agency, NOVELTIS performed an **assessment of the available and most recent global and regional tidal models** (Table 1) **that could potentially be used as alternative corrections for coastal altimetry data**, depending on the regions.

The assessment was performed in the frequency domain, for each of the main tidal components, considering the vector differences with tide gauge observations and tidal estimates obtained from satellite altimetry. The results were carefully analyzed based on maps of differences between the models and the data, considering the fact that some validation observations have also been used to constrain the models through data assimilation or optimal interpolation.

Model	Model type	Resolution	Released
Global			
GOT4.10	Empirical	1/2°	2016
DTU16	Empirical	1/16°	2016
EOT20	Empirical	1/8°	2021
FES2004	Hydrodynamic	1/8°	2004
FES2014b	Hydrodynamic	1/16°	2016
TPXO7.2	Hydrodynamic	1/30°	2009
TPXO8	Hydrodynamic	1/30°	2013
TPXO9v4	Hydrodynamic	1/30°	2019
Regional			
CATS2008	Hydrodynamic	1/16°	2008
RegAT models Med Sea & NEA Australia Arctic Ocean	Hydrodynamic	1/120° 1/60° 1/30°	2019-2020

Table 1: Inventory of the tidal models considered in the study.

Assessment of the tidal models

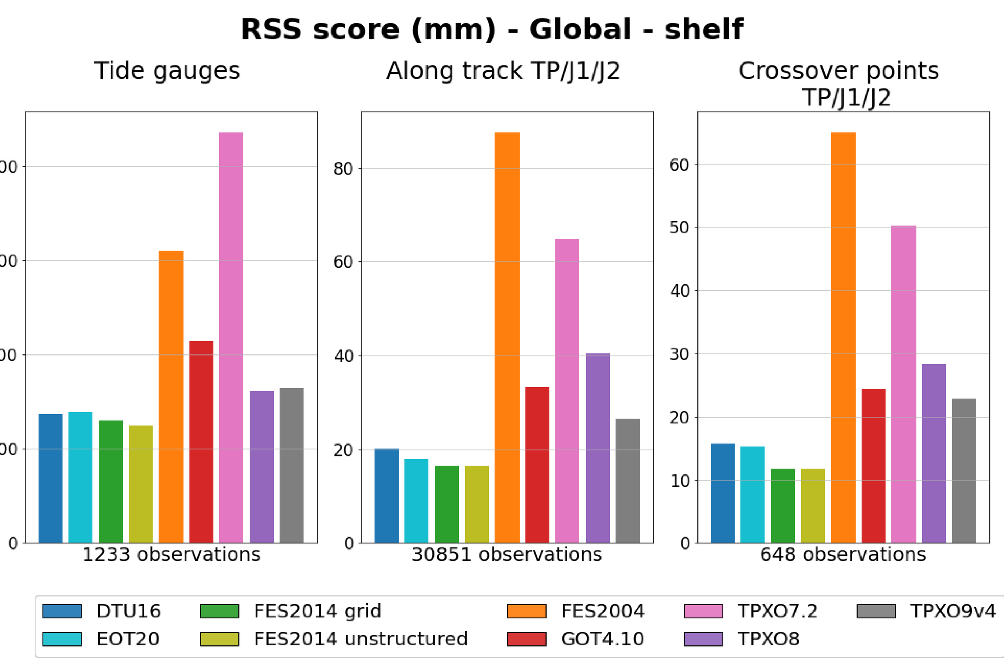
Global assessment

Validation datasets

Tidal harmonic constituents (amplitude and phase lag) **for 8 main tidal waves** (M2, K1, S2, O1, P1, Q1, K2, N2)

- Tide gauge global database
- TP/J1/J2 crossover points and along-track data, only on shelves to avoid artificially lowering the scores with many offshore points with low errors
- CryoSat-2 data in the Arctic Ocean

➔ Parts of the tide gauge and TP/Jason validation datasets have been assimilated/used to constrain the various models so they are not completely independent.



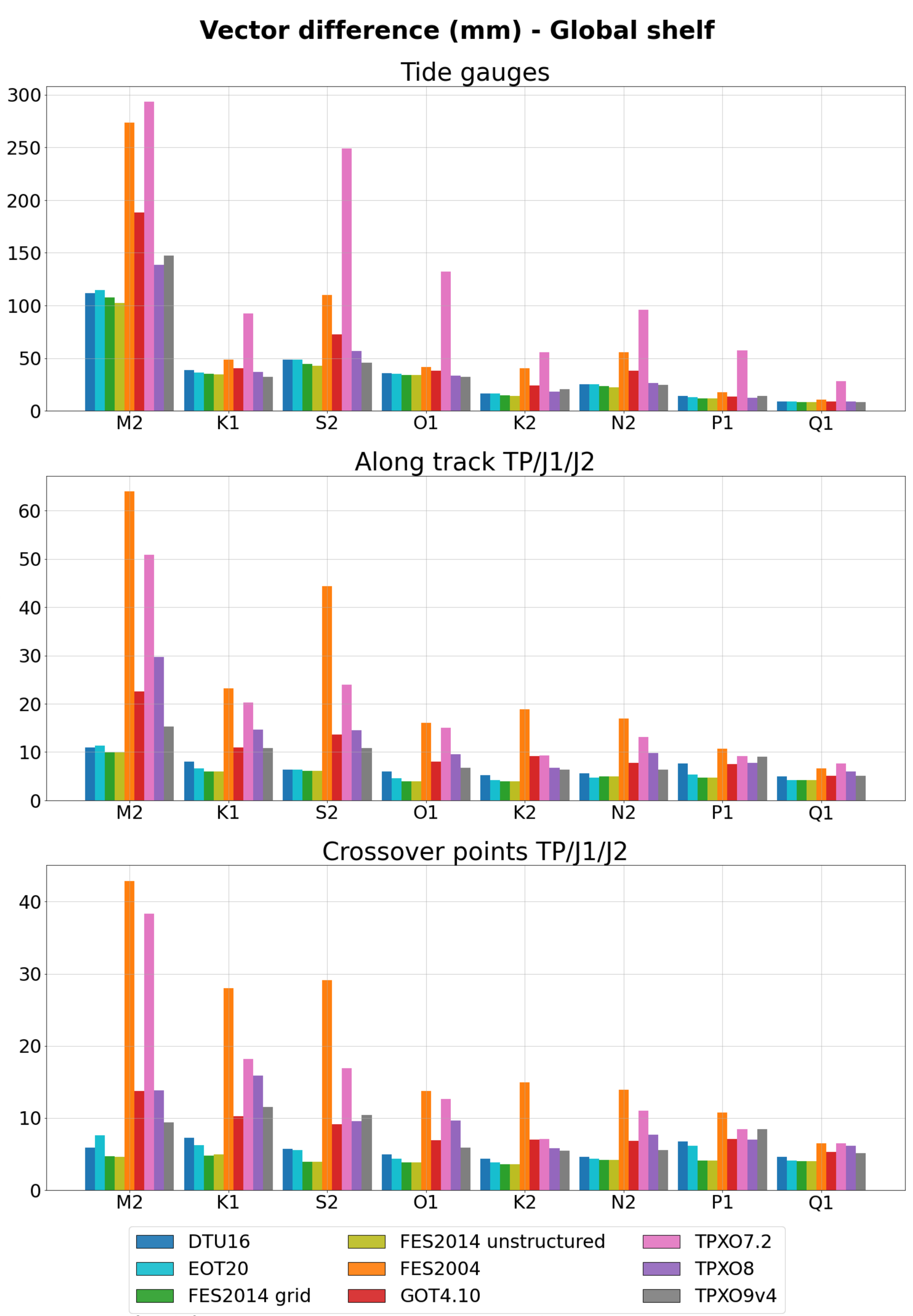


Fig. 1: Vector differences for each tidal wave (right) and overall RSS scores (left) relative to the global databases.

Analysis of the global scores

- ➢ FES2014b globally shows lower errors whatever the validation database (slight improvement noticed with the unstructured grid compared to the regular grid)
- ➢ EOT20 and DTU16 also show good global performance.
- ➢ TPXO9v4 generally shows slightly larger errors than the other recent models.
- ➢ In general, the models differ mostly on the continental shelves, where the tidal amplitudes are larger (Fig. 2).

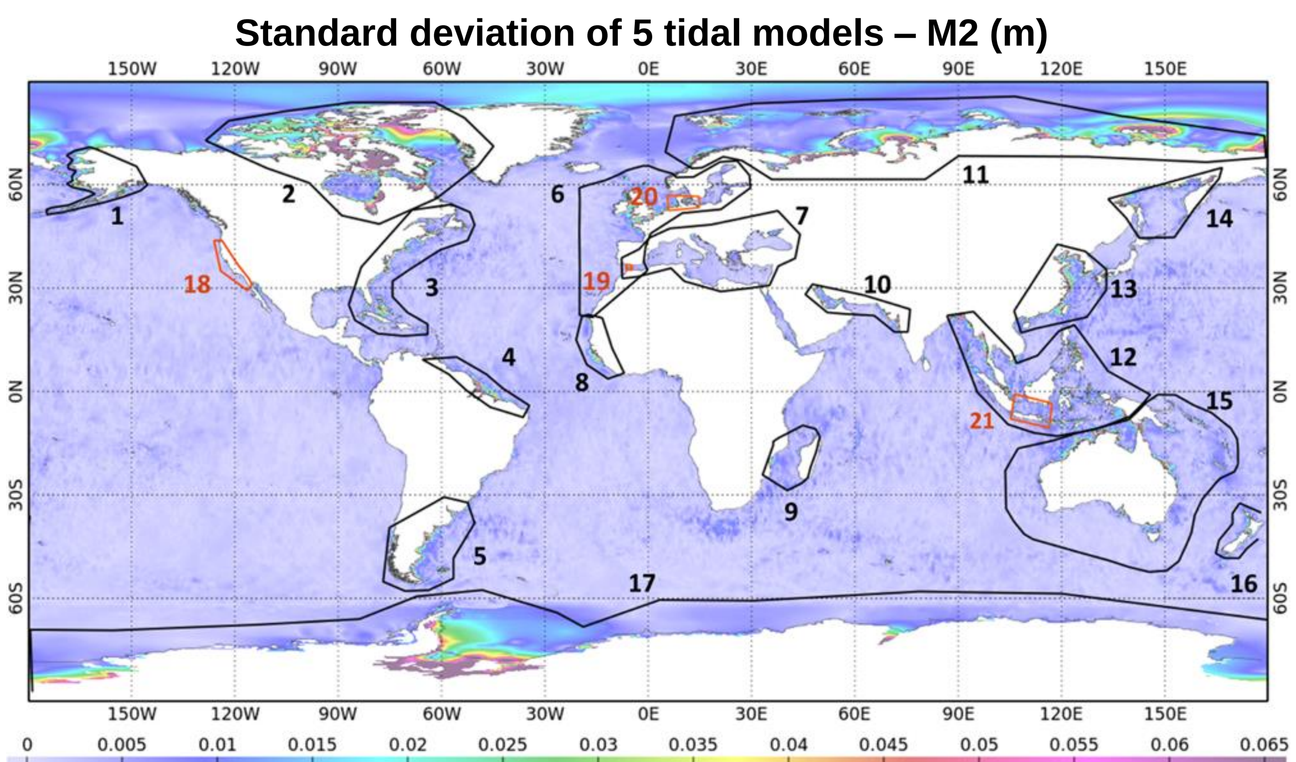


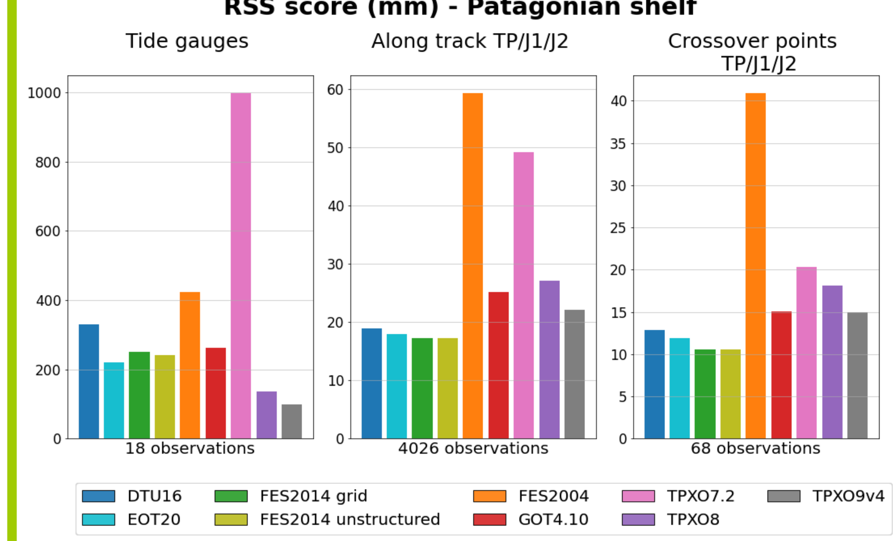
Fig. 2: Vector standard deviation (m) on M2 computed over 5 recent global tidal models (FES2014, TPXO9v4, DTU16, EOT20 and GOT4.10). The polygons show the areas considered for the regional assessment (in orange, the coastal regions of interest of the HYDROCOASTAL project).

Regional assessment: example of the Patagonian Shelf

Analysis of the regional scores and maps

- ➢ Much better overall score for TPXO9v4 at tide gauges, thanks to 1 tide gauge station located in a very enclosed bay, locally not well represented in the other models. Less consistent with altimetry.
- ➢ EOT20 larger errors vs altimetry on M2 and S2 are compensated by lower errors on other tidal waves in the RSS score.

➔ In this region, FES2014b much more consistent with most tide gauges, and with altimetry (partly assimilated).



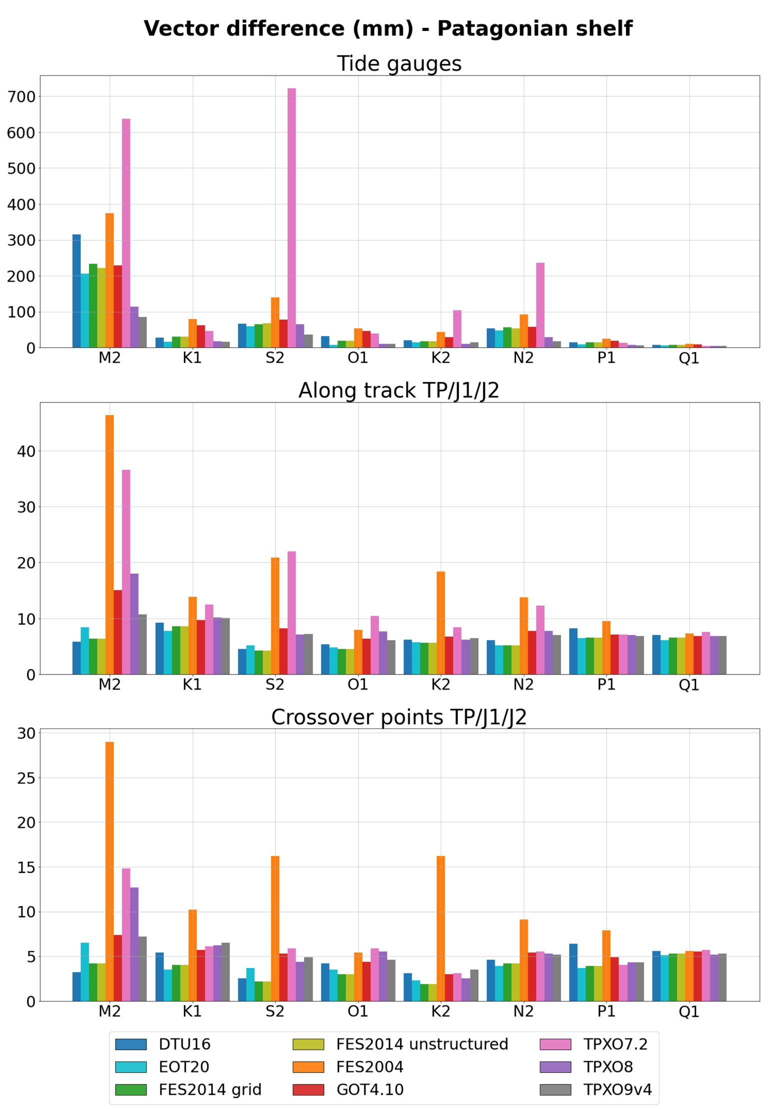


Fig. 3: Vector diff. for each tidal wave (right) and overall RSS scores (left) in the region.

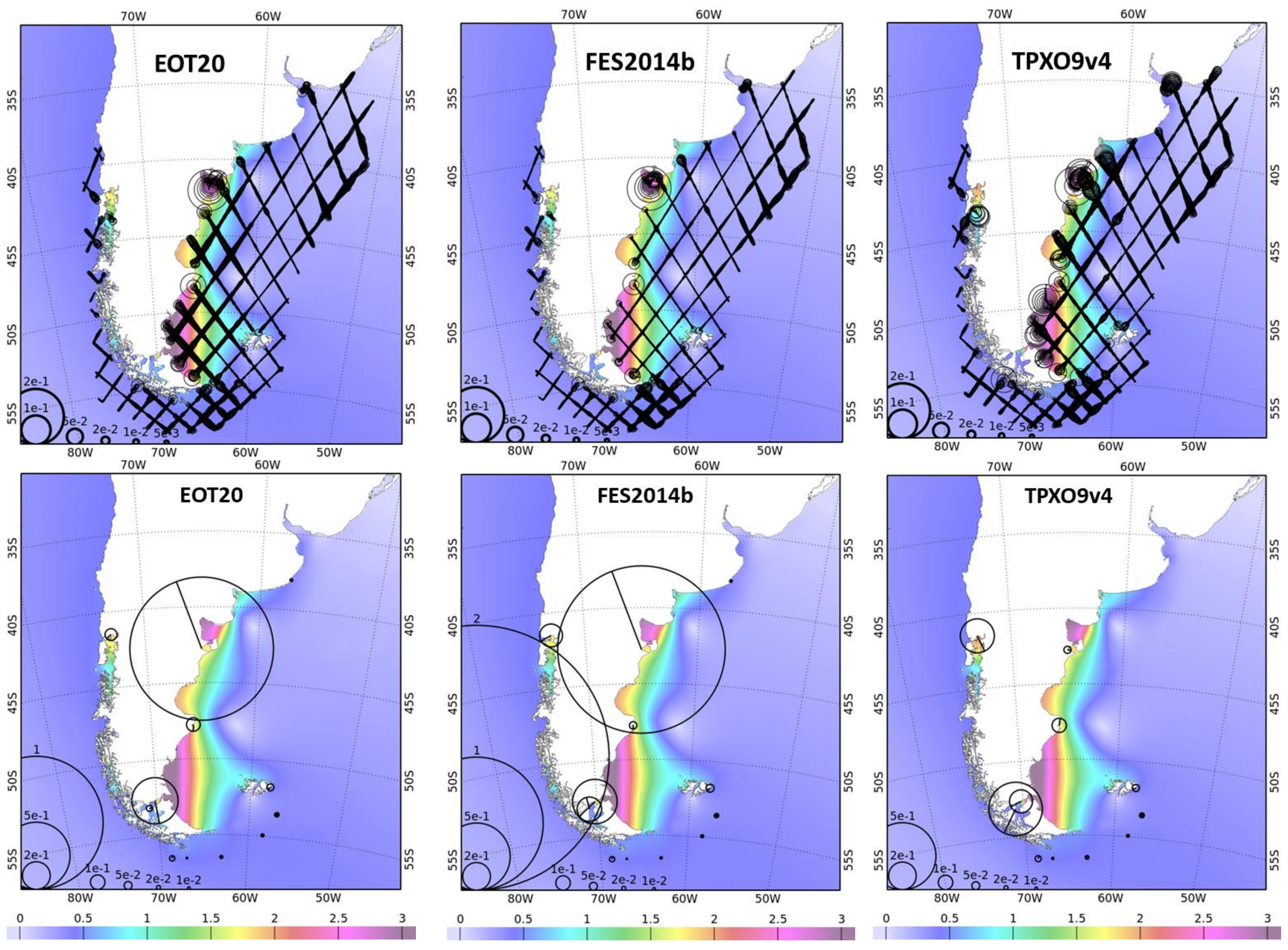
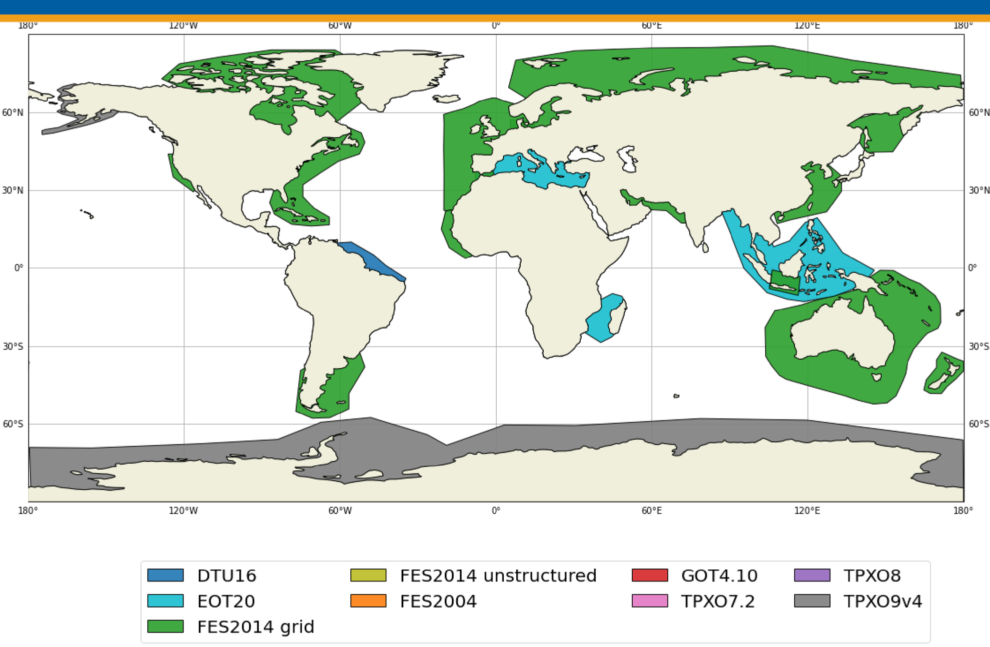


Fig. 4: Vector difference (m) on M2 between the models and the along-track altimetry observations (upper plots) or the tide gauges (lower plots). Background: M2 amplitude (m) of the considered model.

SYNTHESIS AND RECOMMENDATIONS

- Where available, the **high-resolution regional models** generally perform best.
- The **most recent global models** generally show the **best performance**, with **contrasted results** depending on the region (Fig. 5).
- As most non-linear tides develop on the continental shelves, we recommend to **consider tidal models with a rich spectrum, including non-linear tides**, for coastal altimetry applications, in order to limit omission errors in the tidal corrections.
- Computing the tidal corrections from the **unstructured mesh-grids** should be considered in order to fully benefit of the details in the regional models.



- **Compatibility with the DAC-HF correction:** By convention, the MOG2D DAC-HF correction available in the satellite altimetry products is filtered out of the S1 atmospheric tides. To ensure compatibility between the DAC-HF and the ocean tide corrections when considering alternative tidal solutions, altimetry users should consider tidal models that contain the S1 tidal component, which is not the case of all the models assessed within this study.

Fig. 5: Most accurate model per region, considering publicly available global models only. The FES2014b solutions on the unstructured and regular grids show similar performance.