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Coastal altimetry Round Robin

Synthesis on tasks 2.3 (tidal models assessment) and 2.5 (tide gauges selection)

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1. Introduction

In the frame of the round-robin performed by the Coastal Altimetry Working Group of Toulouse (GT côtier) on the coastal altimetry corrections and parameters in 2021 and 2022, NOVELTIS was responsible for two specific tasks, besides their participation in the analysis of the results: the preselection of the tidal models used for the round-robin exercise and the selection of the tide gauges used for the validation of the tested coastal altimetry Sea Level Anomaly (SLA) products.

The preselection of the tidal models for the round-robin exercise was made to reduce the number of candidate models and was based on the assessment of the most recent global and regional tide models, analysing their difference to altimetry and tide gauge validation datasets and considering the suitability of each tidal model spectrum in terms of tidal correction for altimetry sea surface height observations. This analysis was carried out over the shelves at global scale as well as at regional scale on three regions of interest: the North East Atlantic Ocean, East Australia, and the Mediterranean Sea.

The tide gauge stations to be used for the assessment of the Jason-2&3 coastal altimetry SLA products tested within the round-robin were selected following several criteria such as a limited distance to the Jason-2/3 tracks, long and quality time series, and locations in rather simple geography configurations. A harmonic analysis was then performed on these tide gauge sea level time series in order to remove the tidal signal from the record. The de-tided tide gauge time series were then used by the Working Group team for the evaluation of the altimetry products.

2. Task 2.3 - Tidal models assessment

The round-robin exercise performed by the Coastal Altimetry Working Group was based on three years of Jason-2 and Jason-3 observations, and the parameters provided in the Geophysical Data Record (GDR) products were considered as the reference parameters. The Jason-2 and Jason-3 GDR products contain two tidal corrections computed from the GOT4.10 and FES2014b global models.

However, a number of global and regional tidal models have been developed over the past years besides the two reference global ones that are currently included in the altimetry products. Because it was not possible to consider all these alternative models in the round-robin exercise, the aim of this task was to evaluate these models in order to select the most relevant ones to be included in the round robin.

Eleven models have been considered in this evaluation:

- The two solutions provided in the GDR products: GOT4.10, and FES2014b on a regular grid;
- Six other global tidal models: FES2014b on its original unstructured mesh, DTU16, TPXO9v3, v4 & v5, and EOT20;
- Three regional tidal models: the RegAT models around Australia, in the Mediterranean Sea and in the North East Atlantic Ocean.

The analyses have been carried out at global scale as well as at regional scale, on the three regions of interest that were defined for the round robin: the North East Atlantic Ocean, East Australia and the Mediterranean Sea. The selection was based on the tidal components available in the models and on their comparison to altimetry and in-situ validation datasets.

2.1. Tidal components and omission error

The considered models are not all provided with the same spectrum of tidal waves (see Table 1). As a result, they may omit part of the tidal signal.

The amplitudes of the tidal waves vary depending on the region; therefore the dominant waves can vary as well. The largest amplitudes generally originate from the semi-diurnal tidal components (M2, S2, N2, K2...), in the Atlantic Ocean especially, yet in some other regions the diurnal tides (K1, O1) can have the largest magnitudes. In the shelf regions, the non-linear tides develop and can reach amplitudes as large as some of the main linear components. Figure 1 shows the amplitudes of the 10 main tidal components at two tide gauge stations respectively located on the French Atlantic coast and in the Mediterranean Sea. The dominant tidal waves are very different for these two cases. In particular, the M4 quarter-diurnal non-linear tidal component has larger amplitude (almost 20 cm) than the K1 and O1 diurnal waves at the Herbaudière station, in the Atlantic Ocean.

The main non-linear tidal waves (M4, MN4, MS4) are not always available in the tidal models, because they are complex to estimate. However, this can lead to large omission errors in some regions where they can reach several tens of centimetres in total amplitude.

Relatively minor components like Mu2 and Nu2 can also locally reach amplitudes of several centimetres. Some techniques can be used to infer these tidal components from the main linear ones, using admittance computations, but they are generally less accurate than a hydrodynamic simulation.

In general, a rich tidal model spectrum reduces the omission error and can thus remove more tidal signal from the satellite altimetry measurements.

The spatial resolution of the tidal model is also an important aspect, in particular when considering the non-linear tidal components in the shallow coastal regions. Indeed, these components generally develop smaller spatial structures than the main diurnal and semi-diurnal tides, in the range of 50-100 kilometres, possibly fewer locally. Models provided on rather coarse grids will thus tend to strongly smooth the signal of these non-linear tides.

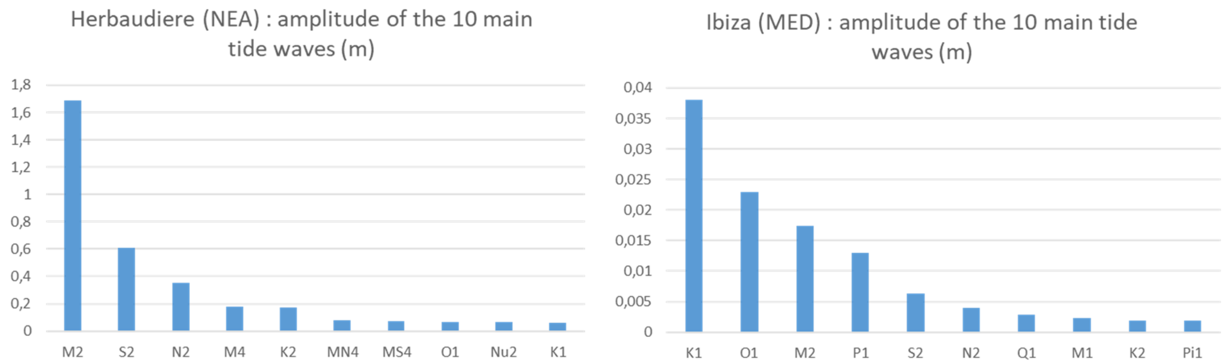

Figure 1: Amplitude (m) of the 10 main tidal components at the Herbaudière tide gauge station (left) located on the French Atlantic coast and at the Ibiza tide gauge station (right) in the Mediterranean Sea. The tide components are ranked as a function of their amplitudes.

Table 1: Resolution and tidal spectrum of the global and regional models considered in this study

Model	Resolution	Tidal components
GOT4.10	1/2°	M2, S2, N2, K2, K1, O1, P1, Q1, S1, M4
DTU16	1/16°	M2, S2, N2, K2, K1, O1, P1, Q1
EOT20	1/8°	M2, S2, N2, K2, 2N2, T2, K1, O1, P1, Q1, S1, J1, M4, Mf, Mm, Sa, Ssa
FES2014b	1/16°	M2, S2, N2, K2, 2N2, Mu2, Nu2, E2, L2, La2, R2, T2, K1, O1, P1, Q1, S1, J1, M3, M4, M6, M8, MKS2, N4, S4, MN4, MS4, Mf, Mm, MSf, MSqm, Mtm, Sa, Ssa
TPXO9v3&4	1/30°	M2, S2, N2, K2, 2N2, K1, O1, P1, Q1, M4, MN4, MS4
TPXO9v5	1/30°	M2, S2, N2, K2, 2N2, K1, O1, P1, Q1, M4, MN4, MS4, S1
RegAT models Med Sea & NEA Australia Arctic Ocean	 1/120° 1/60° 1/30°	M2, S2, N2, K2, 2N2, Mu2, Nu2, E2, L2, La2, R2, T2, K1, O1, P1, Q1, S1, J1, M3, M4, M6, M8, MKS2, N4, S4, MN4, MS4, Mf, Mm, MSf, MSqm, Mtm, Sa, Ssa

2.2. S1 component criterion

As the objective of this assessment is to select tidal models that will be used as tidal corrections for altimetry sea surface height observations, the selected tidal models need to be compatible with the other corrections, and especially with the Dynamic Atmospheric Correction (DAC-HF).

Indeed, the high-frequency signals sampled by the satellite altimeters are mainly linked with the ocean tides and with the effects of the wind and atmospheric pressure on the sea surface height. To remove these high-frequency signals from the satellite altimetry sea surface height measurements, separate corrections are provided for the ocean tides from an ocean tide atlas, and for the high-frequency Dynamic Atmospheric Correction (DAC-HF) from a surge model. However, there are some tight links between these two corrections and they should be cautiously handled.

The S1 and S2 tidal components are composed of a gravitational part due to the Sun and a radiational part due to the diurnal variations in the atmospheric pressure. For S1 in particular, the radiational part is much larger than the gravitational part. Because they are linked with the variations of the atmospheric pressure, the radiational signals of S1 and S2 are also part of the surge elevations estimated when running a surge model with atmospheric pressure forcing, like MOG2D. However, by convention, S1 and S2 are filtered out in the high-frequency DAC correction (MOG2D correction) that is provided in the altimetry products used in the round-robin exercise. These two components must thus be contained in the tidal correction, otherwise the signal is left in the altimetry SSH and generates some aliased signals.

Because it is one of the largest gravitational tidal components, S2 is provided in all the tidal models. S1, however, is not provided in the TPXO9v3 and TPXO9v4 models, nor in DTU16. This means that, even if these models perform well in some regions, they should not be used as is to remove the tides from the altimetry products, unless they are combined with an alternative DAC-HF correction that contains the S1 signal.

The tide models that can ensure compatibility with the DAC are therefore FES2014b, TPXO9v5, EOT20, GOT4.10, and the RegAT regional atlases. The other models are however still considered in the comparison to the validation datasets hereinafter.

2.3. General assessment

The standard deviation of five of the most recent models (DTU16, EOT20, FES2014b, GOT4.10, and TPXO9v4) was calculated and plotted for the M2 wave, which is the tidal component with the highest amplitudes on average (Figure 2). This standard deviation is a complex standard deviation that therefore includes both the amplitude and phase lag variabilities. As expected, the areas showing the largest variability between the models are located where the tidal amplitudes are large (see M2 amplitude on Figure 3), mainly on the continental shelves (see the bathymetry on Figure 4). For M2, these regions are for example the Canadian Arctic Archipelago, the English Channel and the Irish Sea, the Patagonian shelf, the Weddell Sea, the Australian North-West shelf and the Yellow Sea.

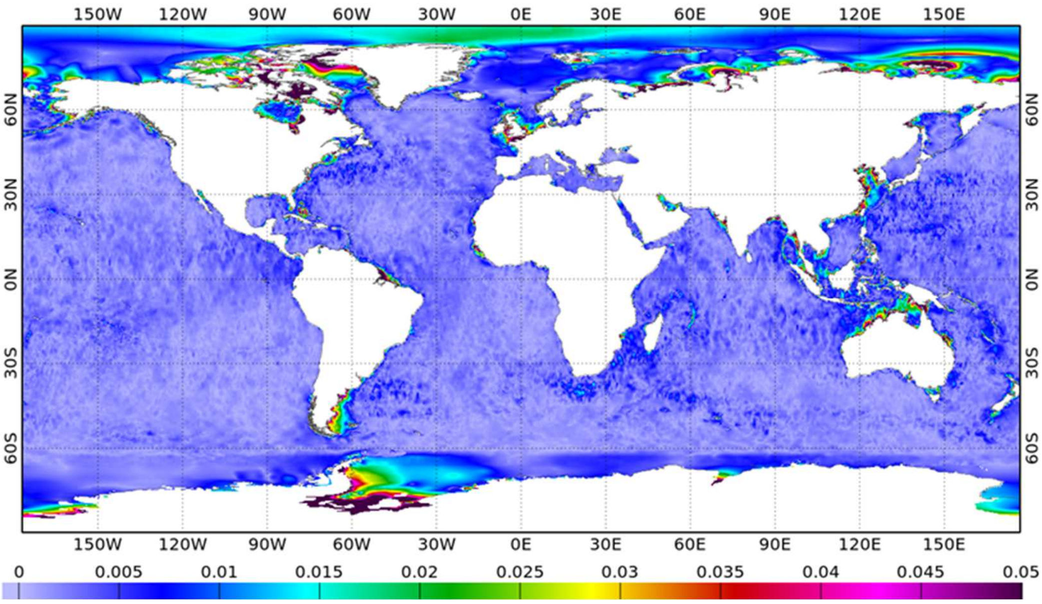

Figure 2: Complex standard deviation of the FES2014b, TPXO9v4, DTU16, EOT20 & GOT4.10 models

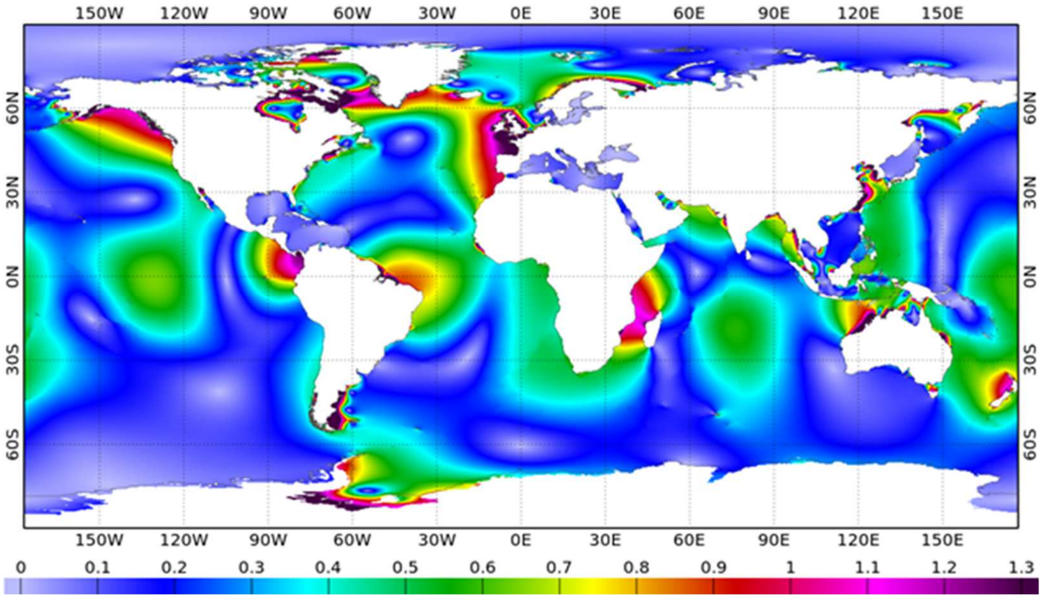

Figure 3: M2 amplitude (m) of the FES2014b global tidal model

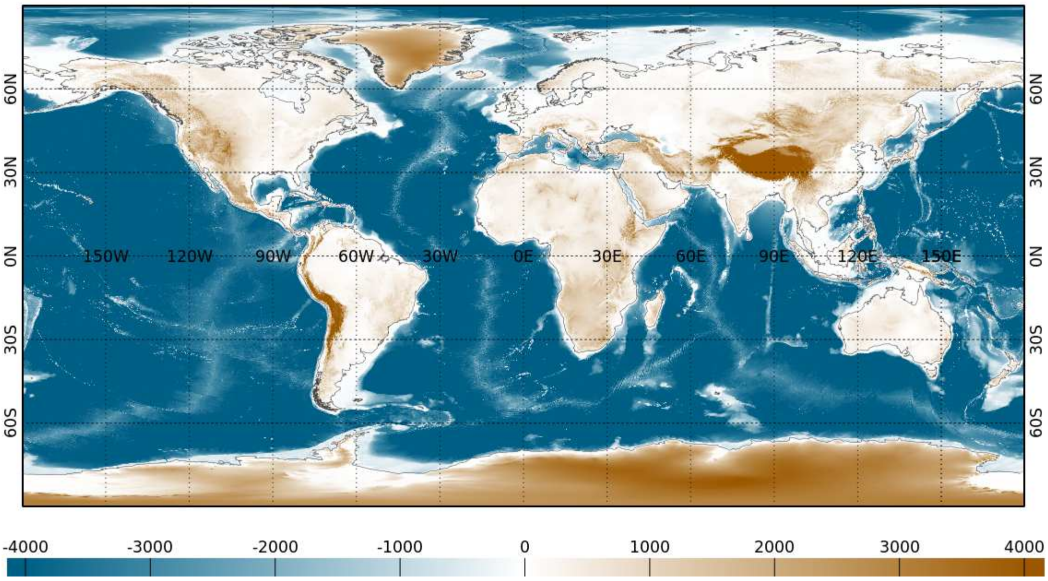

Figure 4: GEBCO-2020 bathymetry (m)

2.3.1. Validation datasets

The assessment of the models has been done in the frequency domain. To this purpose, tidal harmonic constituents (amplitude and phase lag) derived from time series of tide gauge and satellite altimetry sea surface height observations were used.

Three validation datasets were used to assess the models.

a) **Tide gauges:** a collection of 1463 stations gathered and processed by NOVELTIS (Figure 5);
These data originate from different sources such as the University of Hawaii Sea Level Center, EMODnet, and the Japan Oceanographic Data Center, among others.

b) **Along-track altimetry data on the shelves** (Topex-Poseidon/Jason-1/Jason-2) processed in the frame of the FES2014 CNES project (Figure 6);

c) **Altimetry crossover points on the shelves** (Topex-Poseidon/Jason-1/Jason-2) processed in the frame of the FES2014 CNES project (Figure 7).

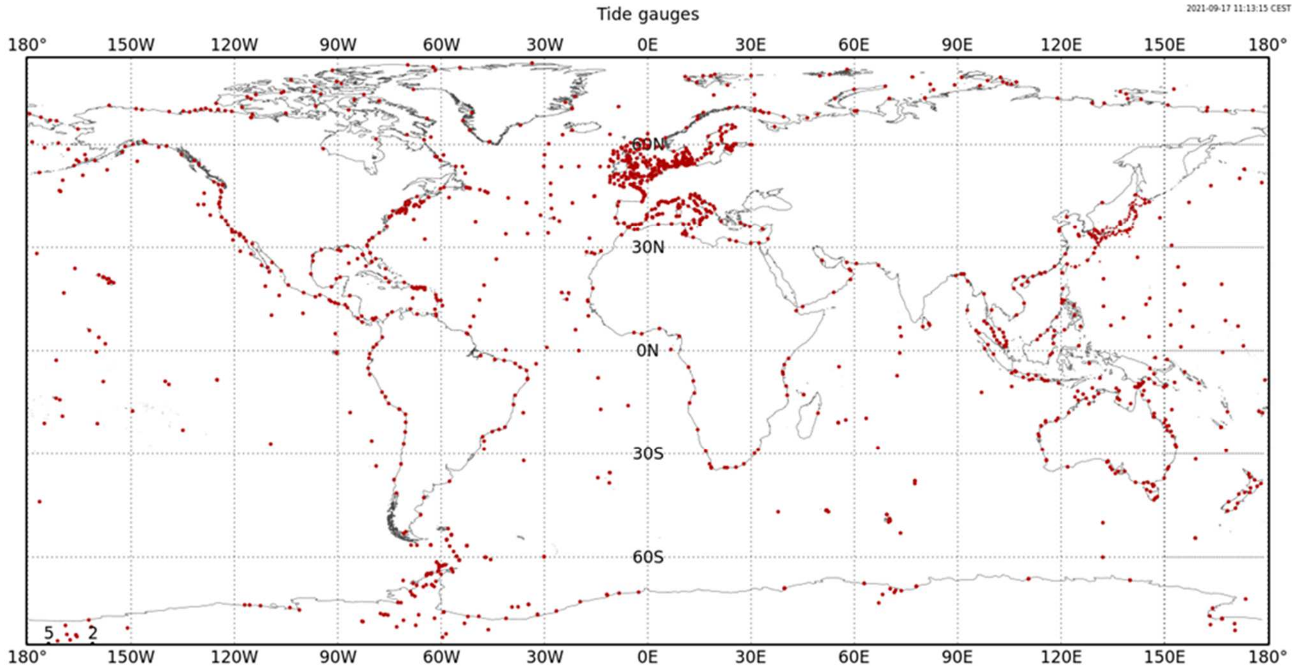

Figure 5: Locations of the tide gauge stations used to evaluate the models

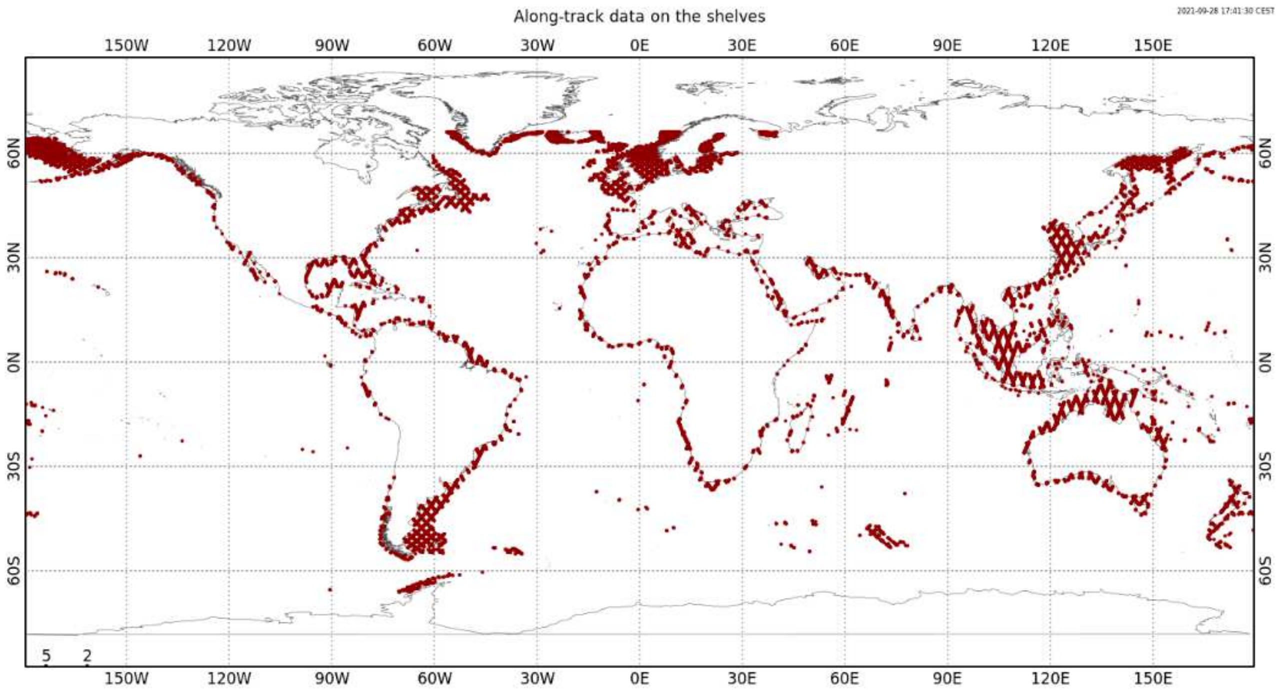

Figure 6: Locations of the Topex/Jason-1/Jason-2 along track altimetry data used to evaluate the models on shelves

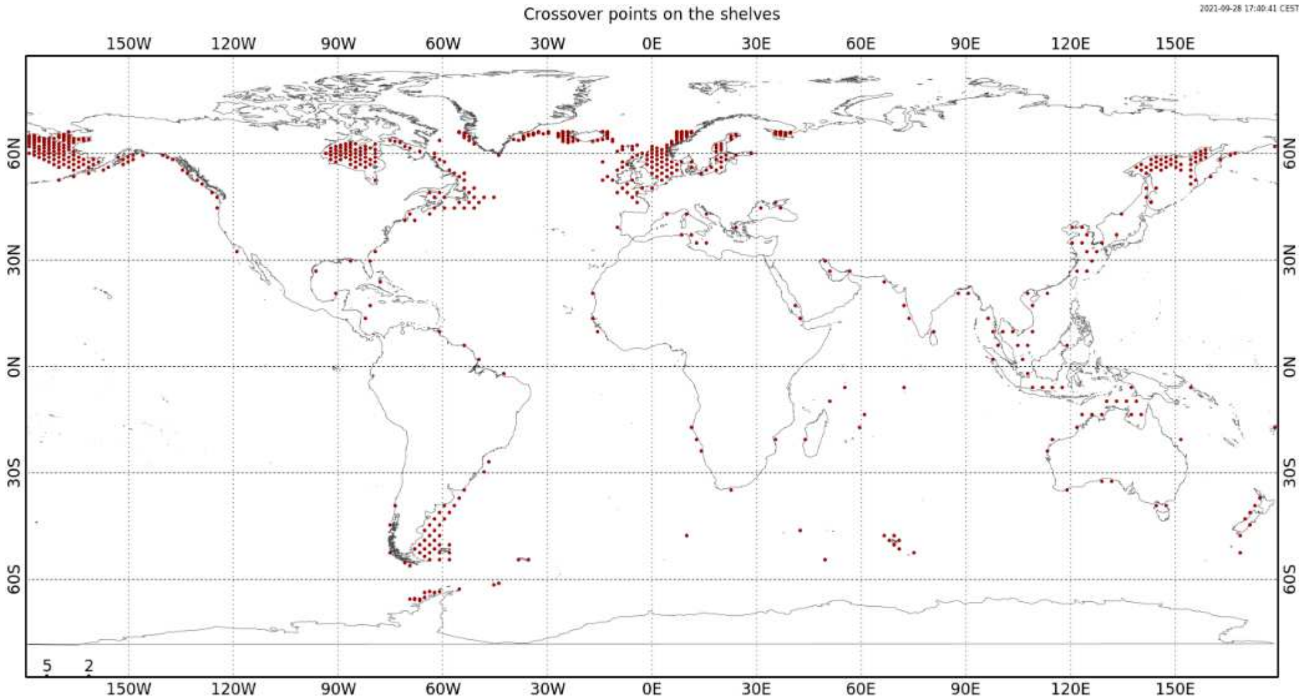

Figure 7: Locations of the Topex/Jason-1/Jason-2 altimetry crossover points used to evaluate the models on shelves

2.3.2. Global evaluation on the shelves

Each global model has been evaluated against the three validation datasets presented above. Figure 8 shows the results of this validation with the vector differences of each tide model for the 8 main tide constituents (M2, K1, S2, O1, K2, N2, P1, and Q1). Figure 9 then shows the root sum square (RSS), which provides a more synthetic result with one single score calculated over the vector differences of these eight main tidal waves. These figures show that FES2014b, EOT20, and DTU16 provide the best results overall. The models of the TPXO family generally show larger differences with the altimetry observations than the other models, however they are generally closer to the tide gauge dataset. Besides, it shows that FES2014b on the unstructured mesh reduces of 3 mm the errors to tide gauges compared to the regular grid. This result is due to a few very coastal stations where the unstructured mesh is finer than the regular grid. Finally, the scores obtained with GOT4.10 are generally much higher than those of the other models, which is mainly due to the coarse resolution of its grid (1/2°) that prevents finely describing the small-scale tidal features on the continental shelves.

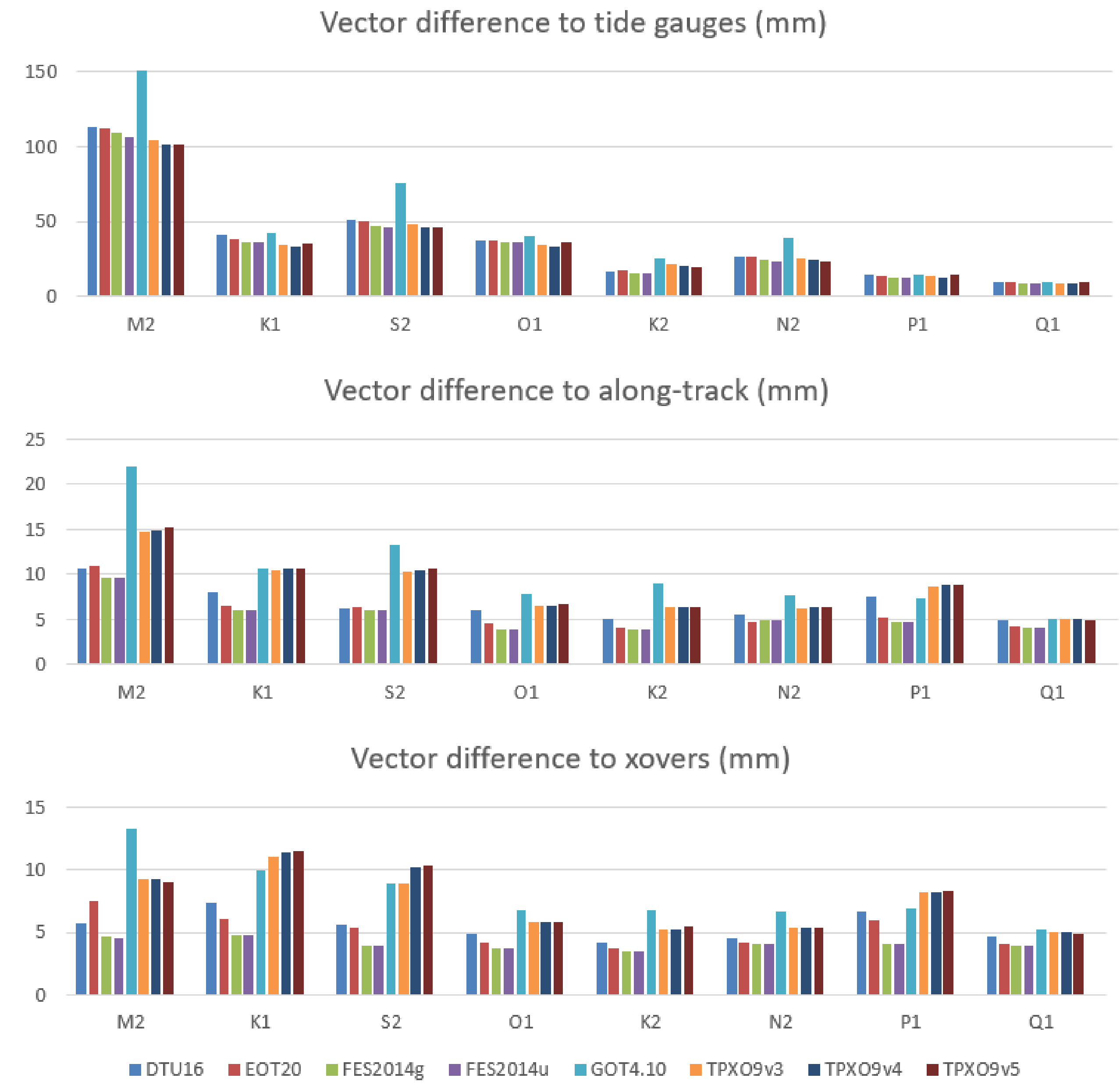

Figure 8: Comparison of the models to the tide gauges (top), the along-track altimetry data (middle) and the altimetry crossover points (bottom): vector difference (mm) for each main tide constituent on the global continental shelves.

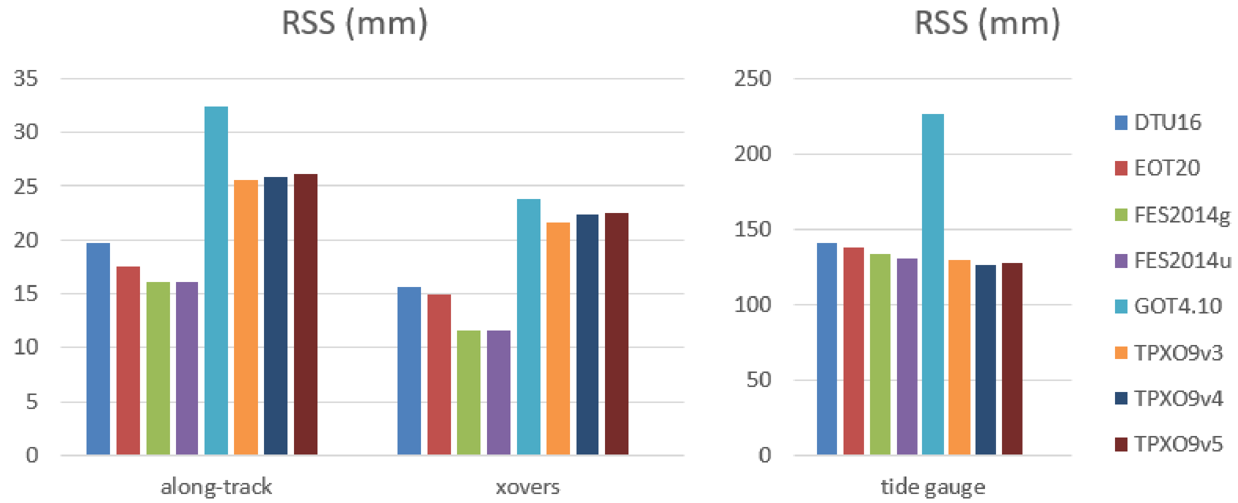

Figure 9: RSS scores (mm) of the tide models on global continental shelves computed from the vector differences of 8 tidal components, at the along-track altimetry points (left), at the altimetry crossover points (middle), and at the tide gauges (right).

2.3.3. Regional evaluation in the North East Atlantic Ocean

Following the same method as for the global assessment on the global shelves, the global and regional models have been evaluated in the three regions of interest of the round-robin exercise (North East Atlantic Ocean, East Australia and Mediterranean Sea). For this purpose, the validation datasets have been subset over each region of interest.

Figure 10 and Figure 11 respectively show the vector differences of all the considered models for all the tide constituents, and their RSS scores in the North East Atlantic Ocean. Overall, FES2014b and the RegAT regional model provide the best results with RSS scores of 7.1 mm and 6.7 mm relative to the along track altimetry data, 10.5 mm and 10.2 mm relative to the altimetry crossover points, and 129 mm and 94 mm relative to the tide gauges. The three versions of the TPXO9 model show little difference and the latest version, TPXO9v5, is not always as close to the observations as the previous ones.

The map of the M2 vector difference relative to altimetry observations (Figure 12) shows that the EOT20 model lower results are due to higher vector differences to the observations mainly in the English Channel and in the Celtic and Irish Seas.

Finally, like for the global assessment, the FES2014b unstructured version reduces the errors to tide gauges by 5 mm compared to the regular grid. This is due to 4 stations located in estuaries and ports, where the regular grid is not as fine as the unstructured mesh, which probably smooths the local small-scale tidal features.

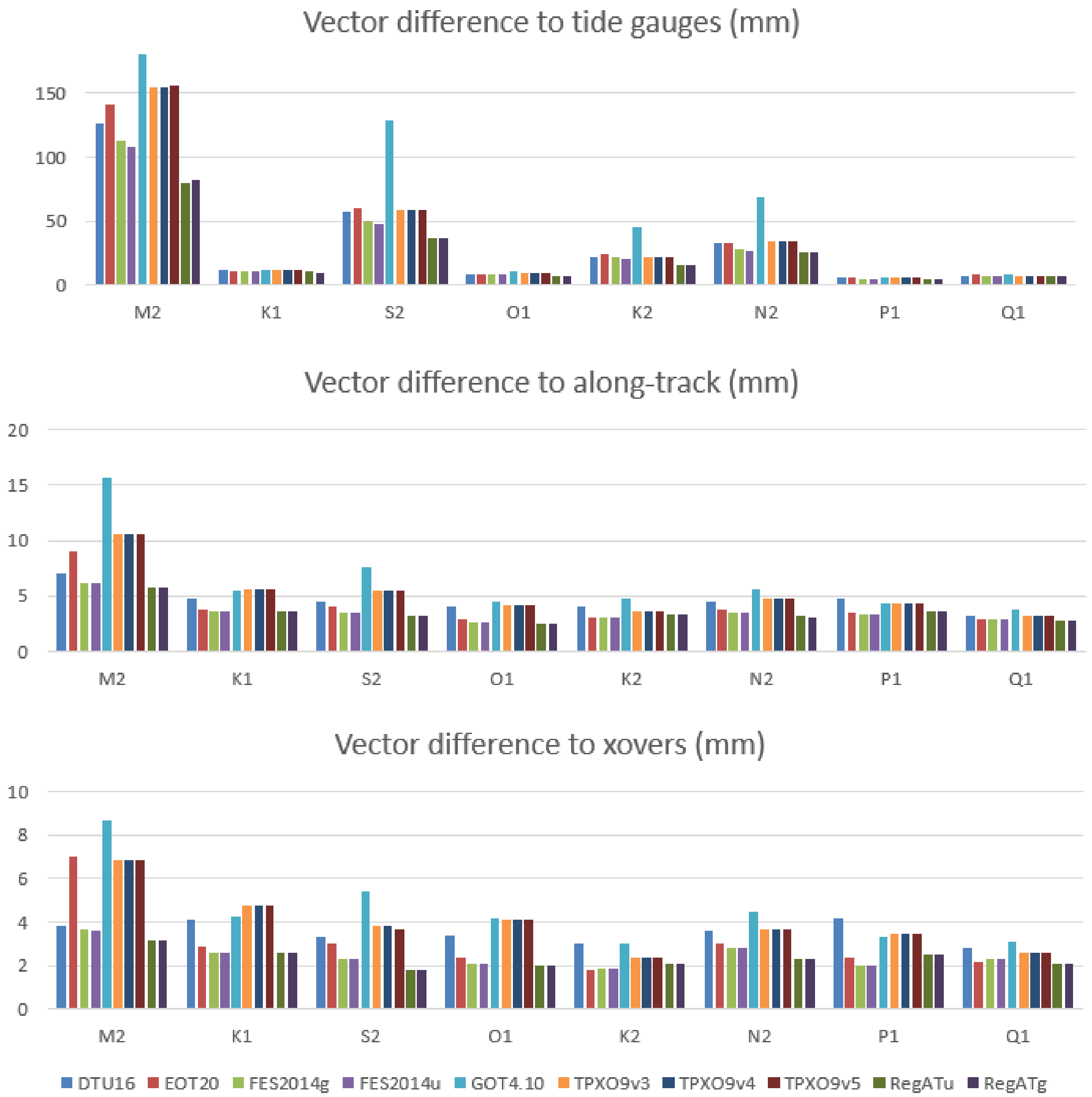

Figure 10: Comparison of the models to the tide gauges (top), the along-track altimetry data (middle) and the altimetry crossover points (bottom): vector difference (mm) for each tide constituent in the North East Atlantic Ocean. u stands for unstructured, g for gridded.

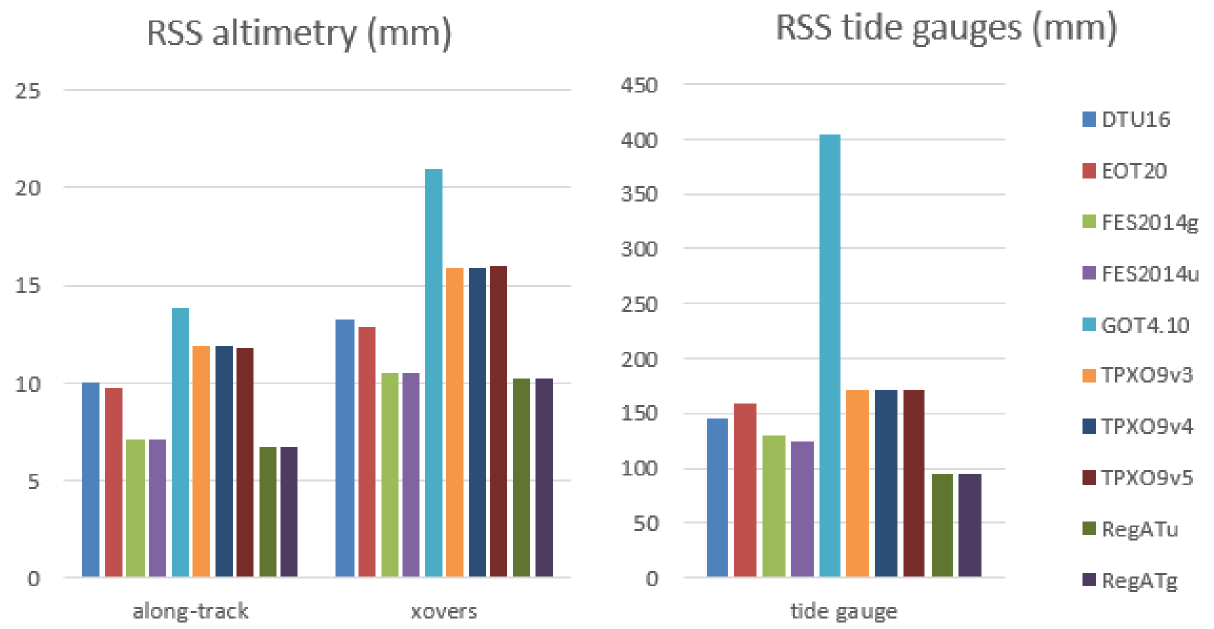

Figure 11: RSS scores (mm) of the tide models in the North East Atlantic Ocean, computed from the vector differences of 8 tidal components, at the along-track altimetry points (left), at the altimetry crossover points (middle) and at the tide gauges (right). u stands for unstructured, g for gridded.

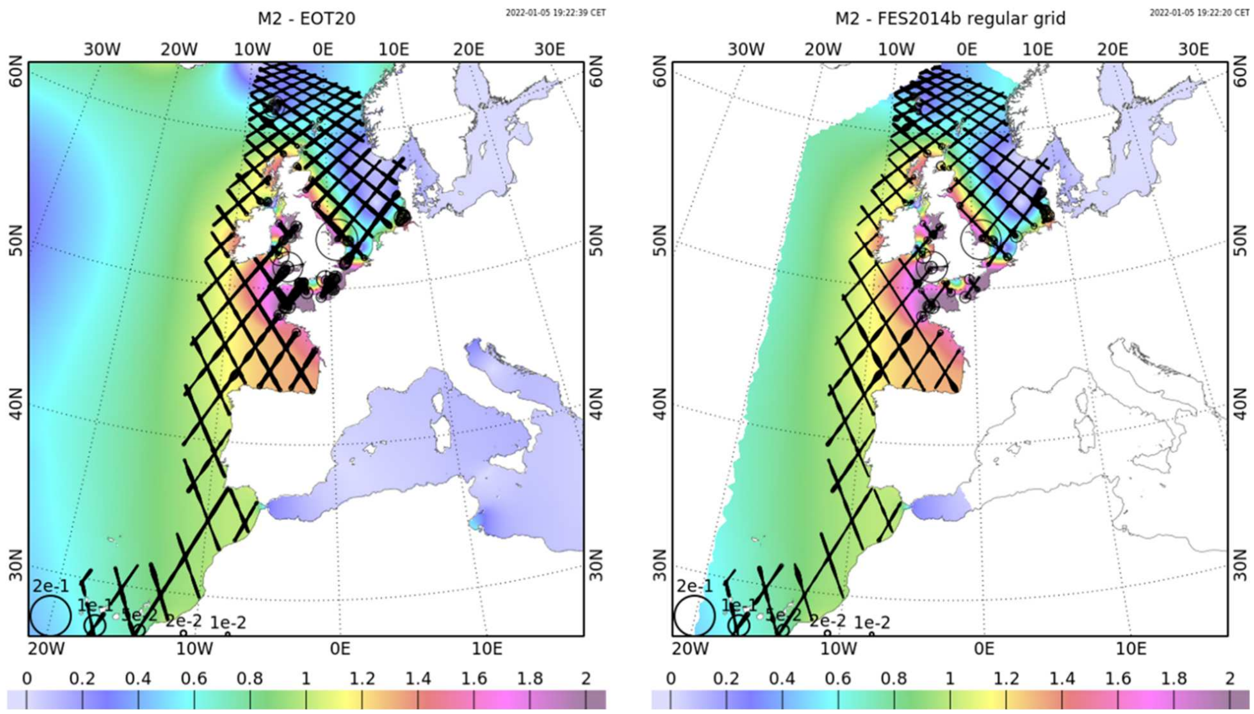

Figure 12: Vector difference (m) on the M2 wave of EOT20 (left) and FES2014b on a regular grid (right) to along-track altimetry data (black) and tide gauges (red) in the North East Atlantic Ocean. The size of the circles is proportional to the vector difference (m) – Background: M2 amplitude (m) of the considered tidal model.

2.3.4. Regional evaluation in East Australia

Figure 13 and Figure 14 respectively show the vector differences of all the considered models for all the tide constituents, and their RSS scores along the East coast of Australia. Figure 15 then shows the map of the M2 vector differences relative to the along-track altimetry data and to the tide gauges for the RegAT-Australia regional model, and the TPXO9v5, FES2014b gridded and EOT20 global models.

The vector difference scores show that the RegAT regional model over Australia provides the best results, for most tidal waves and for all the validation datasets. It also exhibits that, compared to tide gauges, the two versions of theFES2014b model have rather large errors for the main semi-diurnal tidal waves, M2 and S2. The map of these vector differences indicates that these higher scores are due to the tide gauges located in the Torres Strait. Besides, although the latest version of TPXO9 shows reduced differences to the tide gauge observations on the M2, S2 and O1 waves, the errors have increased for the K2, N2 and Q1 waves. Compared to the altimetry observations, the TPXO9v5 results are again not always better than those of the previous versions of the model, especially for the M2, S2 and N2 waves.

Overall, regarding the RSS scores, which synthetise the vector differences for all the tidal waves, the RegAT regional model is the most relevant one over the region with an RSS score of 3.6 cm to tide gauges, 1.9 cm to along-track data and 1.5 cm to crossovers. The most significant difference between the models is observed on the tide gauges, where the RegAT-Australia regional model provides 1.5-cm lower RSS score than the second-best model in the area (TPXO9v5). The results are then contrasted depending on the considered validation dataset. EOT20 appears to be more accurate compared to altimetry observations, whereas TPXO9v5 is closer to the tide gauges. The map of the M2 vector differences shows that, indeed, the TPXO9v5 model presents large errors to altimetry especially in the Torres Strait and in the Coral Sea. In the light of these maps, the results of the RegAT model and EOT20 appear to be more homogeneous.

Finally, in this region the differences between the regular grids and the unstructured ones are sub-millimetric for both FES2014b and the RegAT regional model.

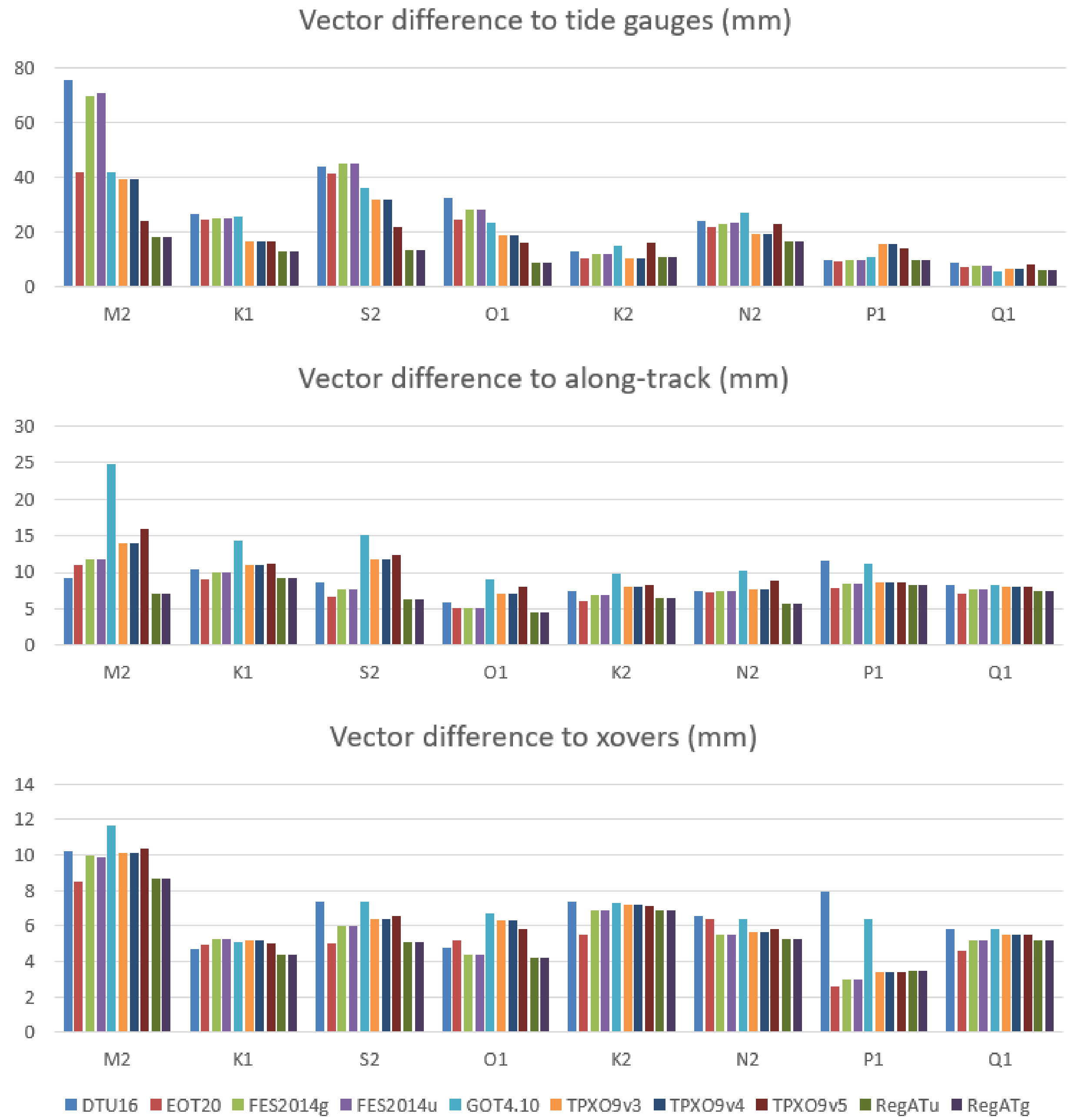

Figure 13: Comparison of the models to the tide gauges (top), the along-track altimetry data (middle) and the altimetry crossover points (bottom): vector difference (mm) for each tide constituent in East Australia. u stands for unstructured, g for gridded.

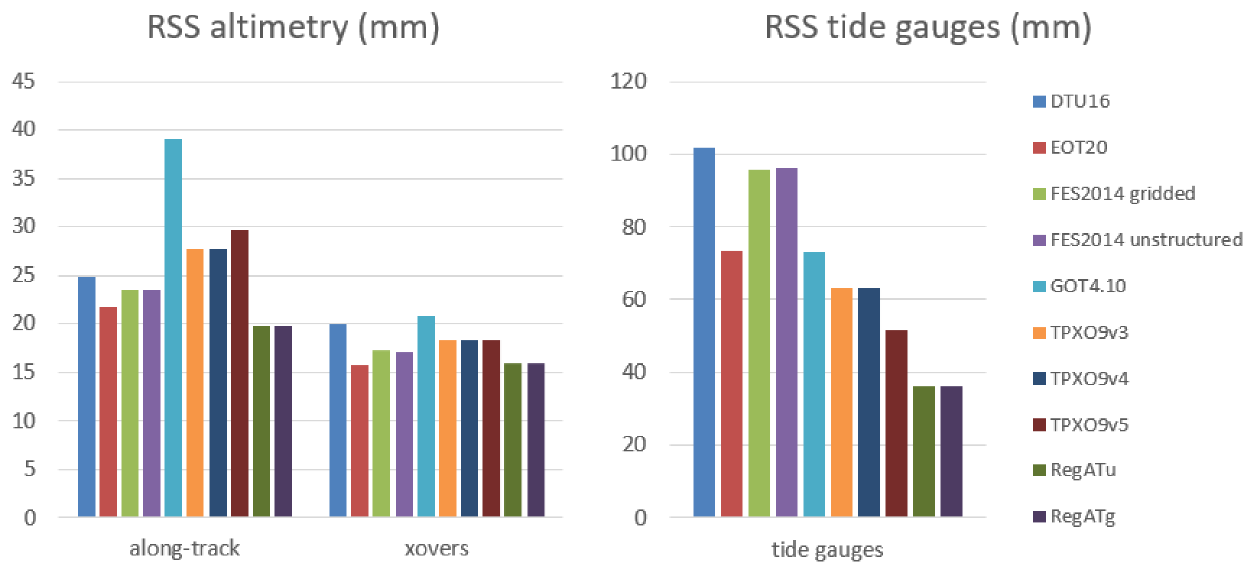

Figure 14: RSS scores (mm) of the tide models in East Australia, computed from the vector differences of 8 tidal components, at the along-track altimetry points (left), at the altimetry crossover points (middle) and at the tide gauges (right). u stands for unstructured, g for gridded.

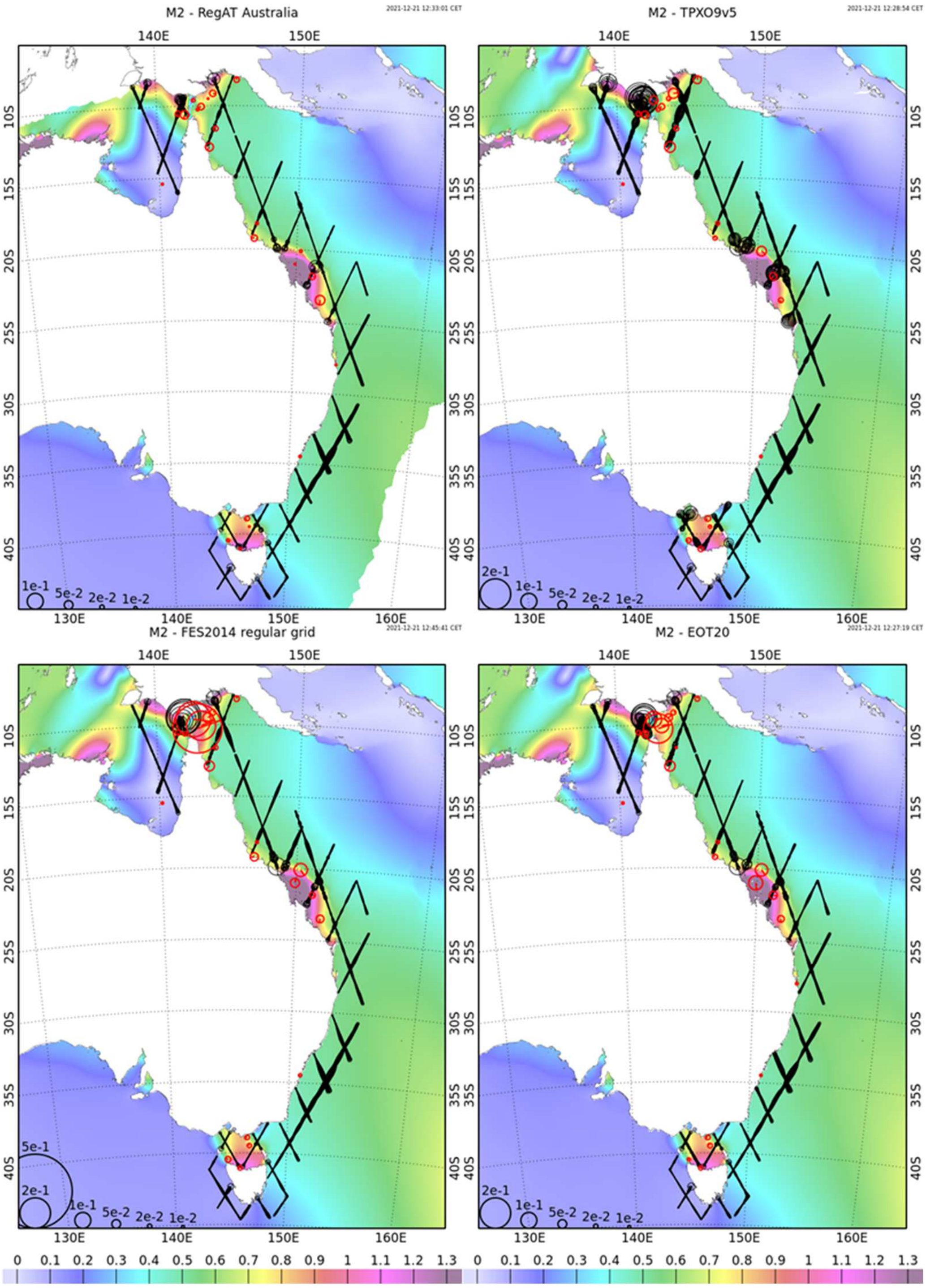

Figure 15: Vector difference (m) on the M2 wave of RegAT Australia (upper left), TPXO9v5 (upper right), FES2014b gridded (lower left) and EOT20 (lower right) to along-track altimetry data (black) and tide gauges (red) in East Australia. The size of the circles is proportional to the vector difference (m) – Background: M2 amplitude (m) of the considered tidal model.

2.3.5. Regional evaluation in the Mediterranean Sea

Figure 16 and Figure 17 respectively show the vector differences of all the considered models for all the tide constituents, and their RSS scores in the Mediterranean Sea. Figure 18 then shows the map of the M2 vector differences to the along-track altimetry data and to the tide gauges for the RegAT Mediterranean Sea regional model and for the FES2014b unstructured, TPXO9v5 and EOT20 global models. In this region, the results of the models are much less contrasted (overall differences of a few millimetres) because of the globally low tidal amplitudes.

In more details, Figure 16 shows that the RegAT regional model over the Mediterranean Sea provides fine results relative to all the validation datasets and for all the tidal waves. The TPXO9v4 and v5 models appear to reduce the vector differences to tide gauges compared to TPXO9v3. The TPXO9v5 model shows better results to tide gauges than the other models, yet its vector differences to the altimetry dataset remain slightly higher than those of FES2014b and EOT20, especially for M2.

The RSS scores indicate that, considering all the tidal waves, the RegAT model provides the best results (9 mm to along-track altimetry data, 5 mm to crossover points and 1.8 cm to tide gauges). As for the other regions, the results are contrasted for the other models depending on the validation dataset, as TPXO9v5 shows better results to tide gauges but EOT20 is better relative to altimetry. The map of the M2 vector differences exhibits that TPXO9v5 has better results to tide gauges mostly thanks to the stations located in the Gulf of Gabes, where EOT20 and FES2014b present higher errors. Elsewhere, the TPXO9v5 results relative to the other tide gauges are rather similar to those of FES2014b and RegAT. In the Adriatic Sea finally, EOT20 appears to have lower accuracy to tide gauges than the other global models. The comparison to the along-track altimetry data indicates that TPXO9v5 is generally less accurate than EOT20, RegAT and FES2014b, in particular in the eastern part of the Mediterranean Sea and in the Aegean Sea as shown in Figure 18.

Like for East Australia, the differences between the regular grids and the unstructured ones are sub-millimetric for both FES2014b and the RegAT regional model.

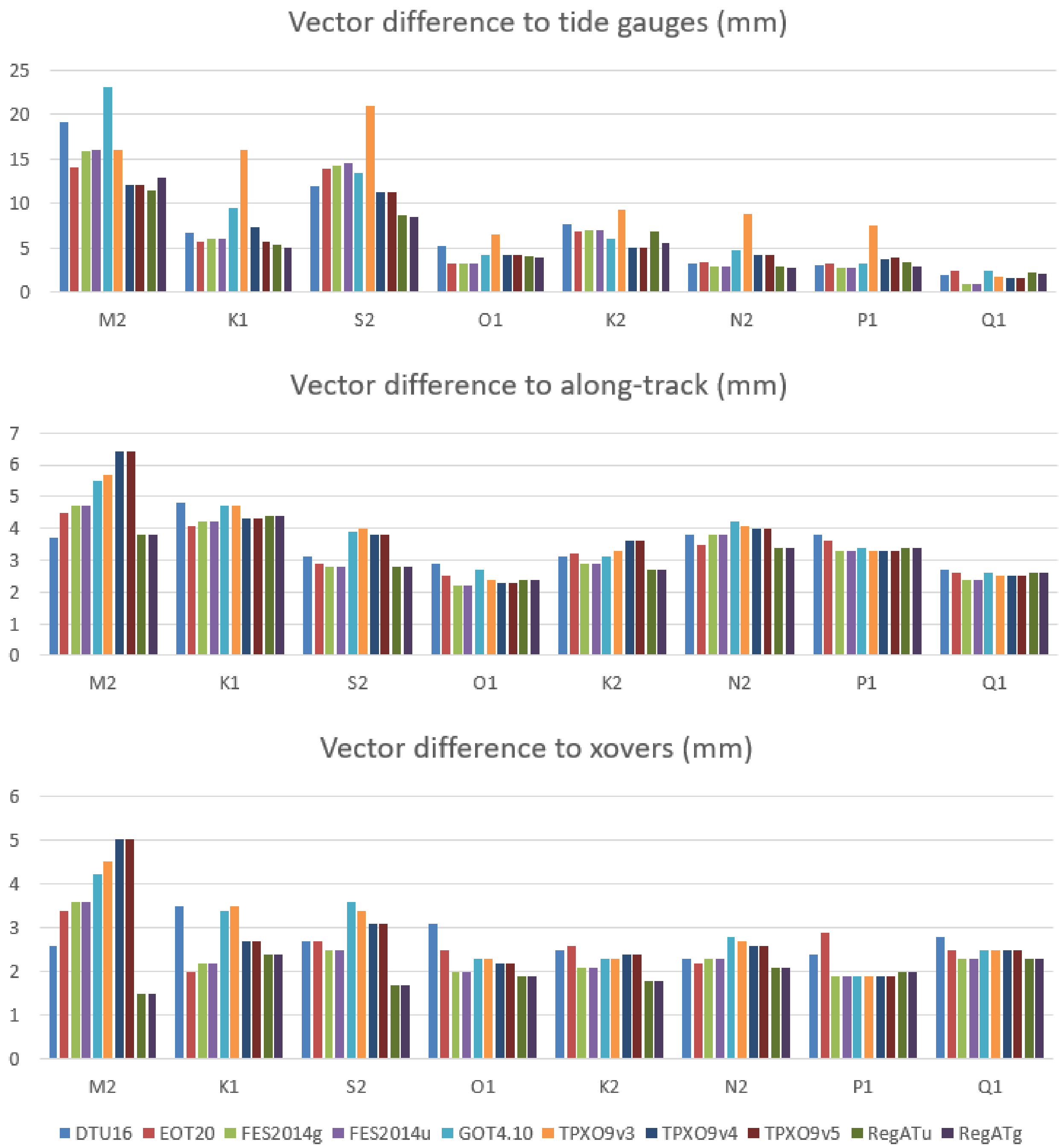

Figure 16: Comparison of the models to the tide gauges (top), the along-track altimetry data (middle) and the altimetry crossover points (bottom): vector difference (mm) for each tide constituent in the Mediterranean Sea. u stands for unstructured, g for gridded.

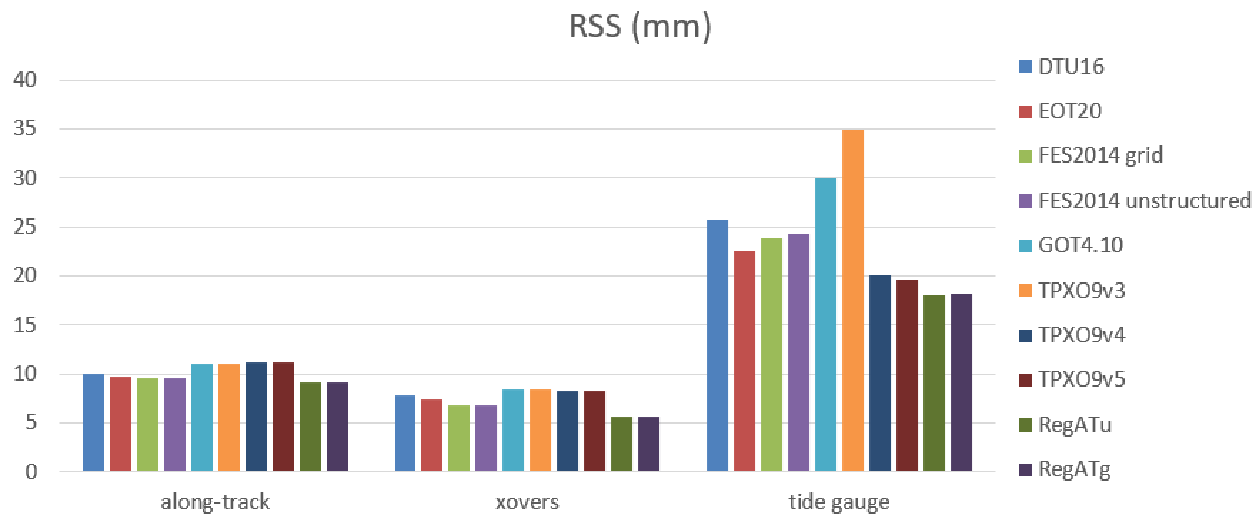

Figure 17: RSS scores (mm) of the tide models in the Mediterranean Sea, computed from the vector differences of 8 tidal components, at the along-track altimetry points (left), at the altimetry crossover points (middle) and at the tide gauges (right). u stands for unstructured, g for gridded.

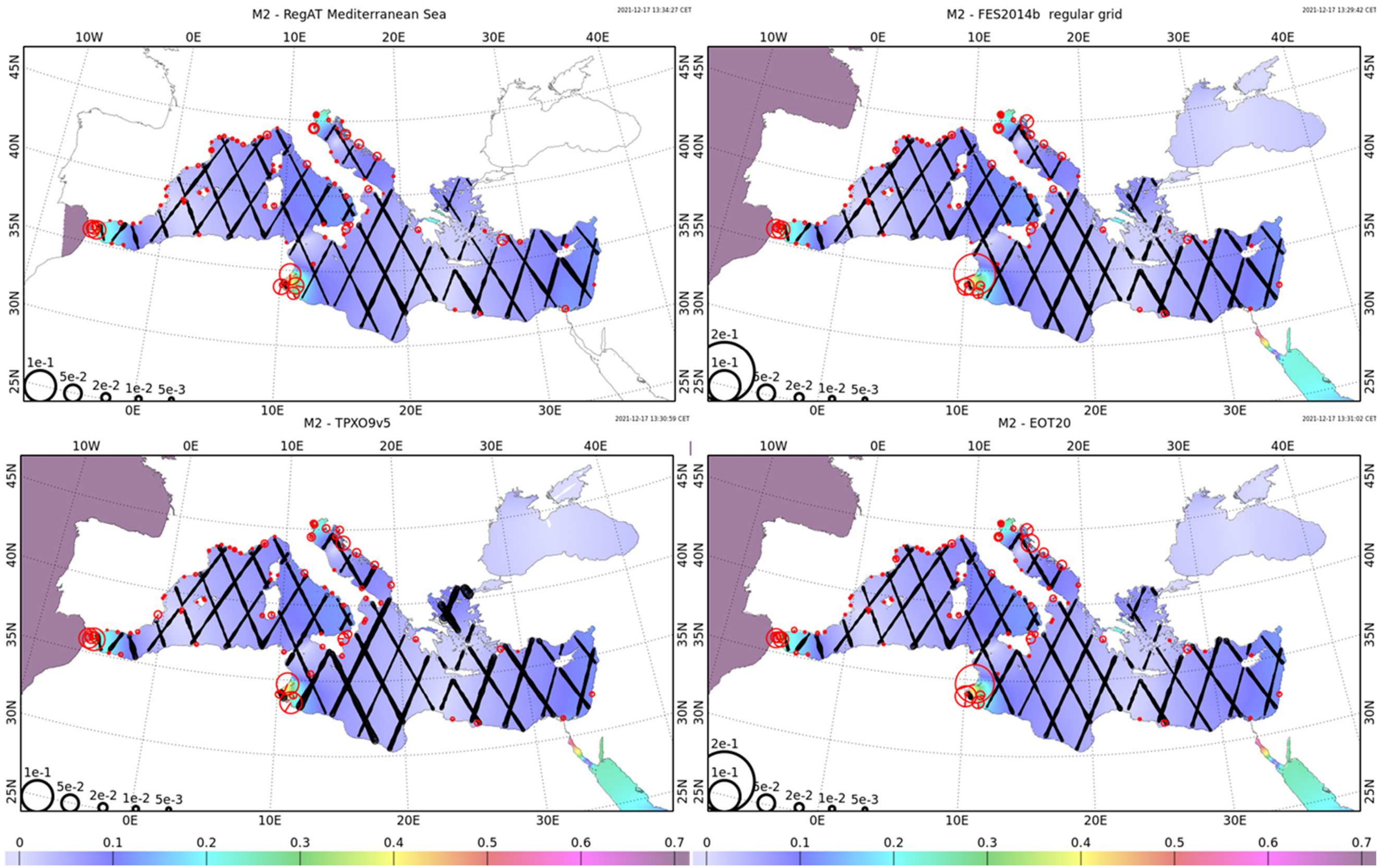

Figure 18: Vector difference (m) on the M2 wave of RegAT Mediterranean Sea (upper left), FES2014b unstructured (upper right), TPXO9v5 (lower left) and EOT20 (lower right) to along-track altimetry data (black) and tide gauges (red) in The Mediterranean Sea. The size of the circles is proportional to the vector difference (m) – Background: M2 amplitude (m) of the considered model.

2.3.6. Difference between regular and unstructured grids

As previously mentioned, the RegAT regional models and the FES2014b global model were originally implemented on unstructured finite-element grids. Then, they were projected on regular grids to ease their handling by users. Both grids were considered in the evaluation of the models because the tidal corrections for the altimetry observations can be computed on either grid. The global and regional assessments of these models, considering the two grid versions, have shown very little differences considering the results to altimetry. However, compared to tide gauges, which are usually located in very coastal regions, the vector differences vary more. On the global continental shelves, and in the North East Atlantic Ocean, the unstructured mesh grids provide better results, whereas in the Mediterranean Sea and in East Australia, the regularly gridded version is sometimes slightly closer to the observations.

Besides these considerations, the gridded version can locally have a smaller extent, due to the staircase effect of the regular grid. Figure 19 shows an example of the difference between the two grids of the RegAT model in the Mediterranean Sea. It demonstrates that more coastal J2-J3 altimetry points are lost due to missing tide corrections when considering the regular grid.

To limit this coastal effect, the tidal models on regular grids that are used to provide tidal corrections for altimetry observations in the GDR products are generally extrapolated by several pixels over the coast. This enables to reduce the loss of coastal altimetry points. However, depending on the resolution of the model grid and on the size of the local tidal structures, this approach can strongly smooth the tidal signal, or even export some offshore tidal information in regions where it may strongly differ (in the case of a very indented coastline with deep fjords for example).

It is also possible to limit the loss of coastal points in the case of the unstructured mesh, for example by considering the closest mesh cell for each altimetry point that falls out of the model grid, up to a certain distance that should be consistent with the spatial scale of the tidal features and the model local resolution.

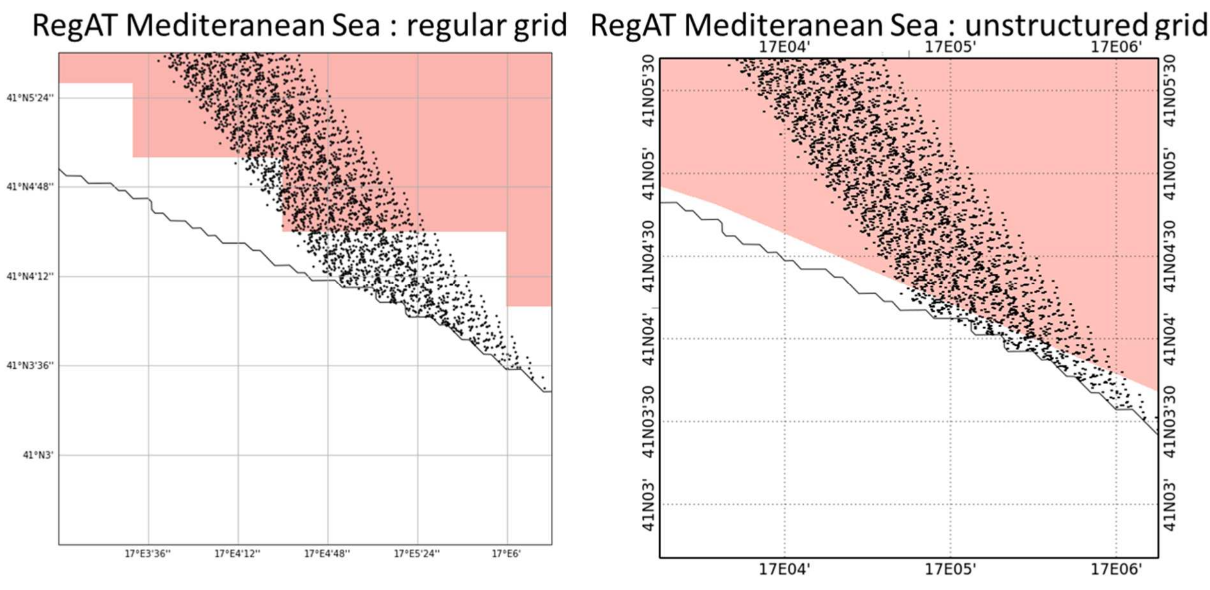

Figure 19: Example of the difference between the regular grid (left) and the unstructured mesh (right) for the RegAT model in the Mediterranean Sea and locations of the J2-J3 along-track altimetry points in the area.

2.4. Synthesis

The objective of this study was to pre-select a reduced number of tidal models for the coastal altimetry round-robin exercise, as the number of candidate tidal models is large compared to all the other coastal altimetry corrections and parameters that are tested within the round robin. The conclusion of this model comparison led to a selection of 4 tidal models. A strong selection criterion was the availability of the S1 tidal component in the model tidal spectrum (to ensure compatibility with the DAC correction), which eliminated DTU16 and the TPXO9v3 and v4 models. We also selected models that provided fine and homogeneous results relative to the three validation datasets and that contain a relevant number of tidal waves in order to accurately represent the whole tide signal. The TPXO9v5 model was thus discarded due to its contrasted results depending on the regions and its general lower accuracy to altimetry observations.

Finally, in addition to the tide corrections already available in the GDR products (FES2014b gridded and GOT4.10), we proposed to assess within the round robin the FES2014b unstructured model, EOT20, and the RegAT gridded & unstructured models in each region on interest.

3. Task 2.5 - Tide gauges selection

In order to assess the coastal altimetry SLA products generated in the frame of the round-robin, relevant tide gauge stations had to be selected in the three regions of interest: the Mediterranean Sea, the North East Atlantic Ocean and East Australia. The aim of this task was to select relevant stations, about ten in each region, preferably homogeneously distributed, close to the Jason-2/3 tracks, and covering the time periods considered for the round robin (3 years for each mission). Because the objective was to compare the instantaneous 20-Hz altimetry observations with the tide gauge data, the tide gauge observations had to be high-frequency (1-hour time step max). Moreover, the comparison was to be performed on SLA corrected from the tide and the surge (DAC) both for altimetry and tide gauges. For the tide gauges, the tides were removed thanks to a harmonic analysis, which required quality time series with a limited number of (small) gaps.

To this purpose, the following selection criteria have thus been applied:

- A recording period from 2013 to 2019;
- Hourly time series;
- Stations located at less than 50 km from the Jason-2/3 tracks;
- Stations whose elevation time series do not contain too many gaps (see example on Figure 20);
- Quality time series: removal of punctual spikes and jumps, verification of the absence of drift, saturation plateaux, clock problems (resulting in shifts with the tides), etc.…
- Stations not located too deep in estuaries and bays, to avoid very complex tidal signals (see example on Figure 21).

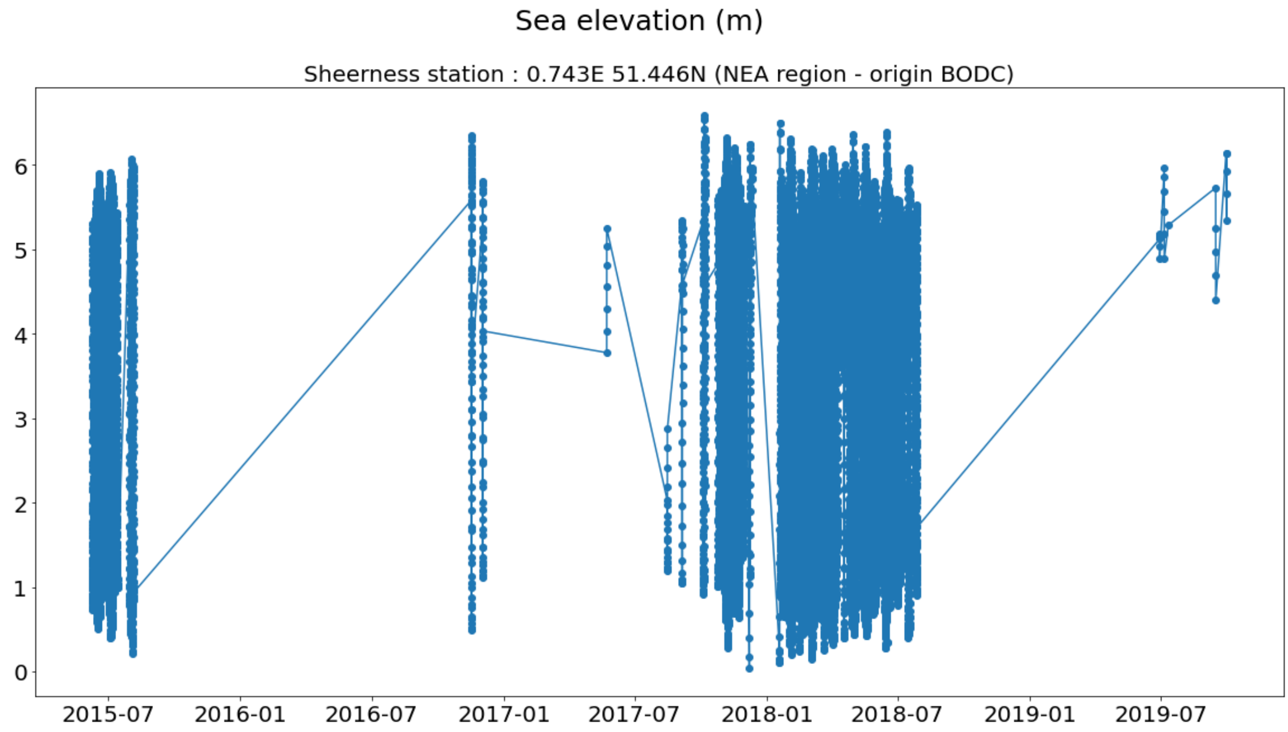

Figure 20: Example of the Sheerness station, located in the North East Atlantic Ocean, whose elevation time series contains too many long gaps to perform a tidal analysis.

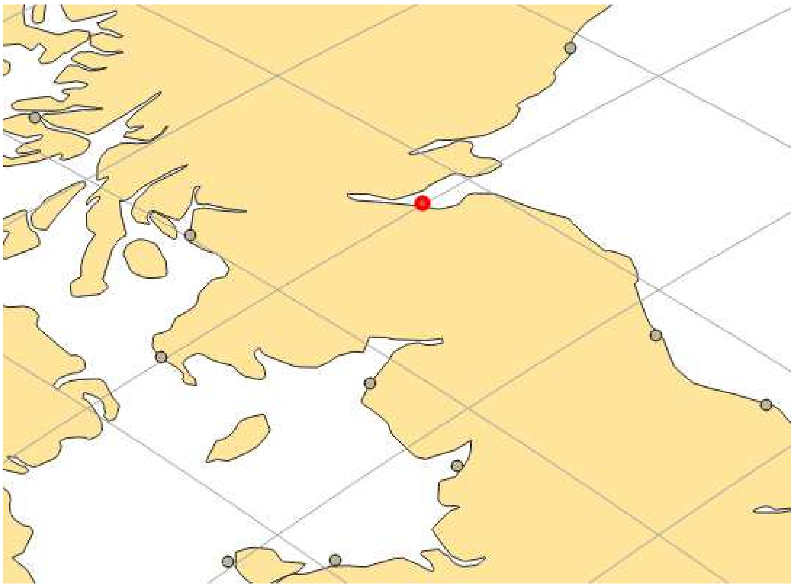

Figure 21: Example of a tide gauge station (red dot) located too deep in an estuary. The grey lines represent the Jason-2/3 tracks.

Several data sources have been explored in order to access relevant stations:

- The Copernicus Marine Service catalogue (CMEMS) (Mediterranean Sea);
- The SHOM data portal : (Mediterranean Sea and North East Atlantic);
- The Italian National Tide gauge Network (Mareografico) (Mediterranean Sea);
- The Turkish National Sea Level Monitoring System (TUDES), specifically requested by NOVELTIS for this project (Mediterranean Sea);
- The British Oceanographic Data Centre (BODC) (North East Atlantic);
- The University of Hawaii Sea Level Center (UHSLC) (North East Atlantic and Australia);
- The Australian Bureau of Meteorology (BOM), specifically requested by NOVELTIS for the BATHY CNES project (Australia).

The inventory of the available observations and the selection criteria led to a validation database composed of 34 stations: 8 in Australia, 13 in the Mediterranean Sea and 13 in the North East Atlantic Ocean.

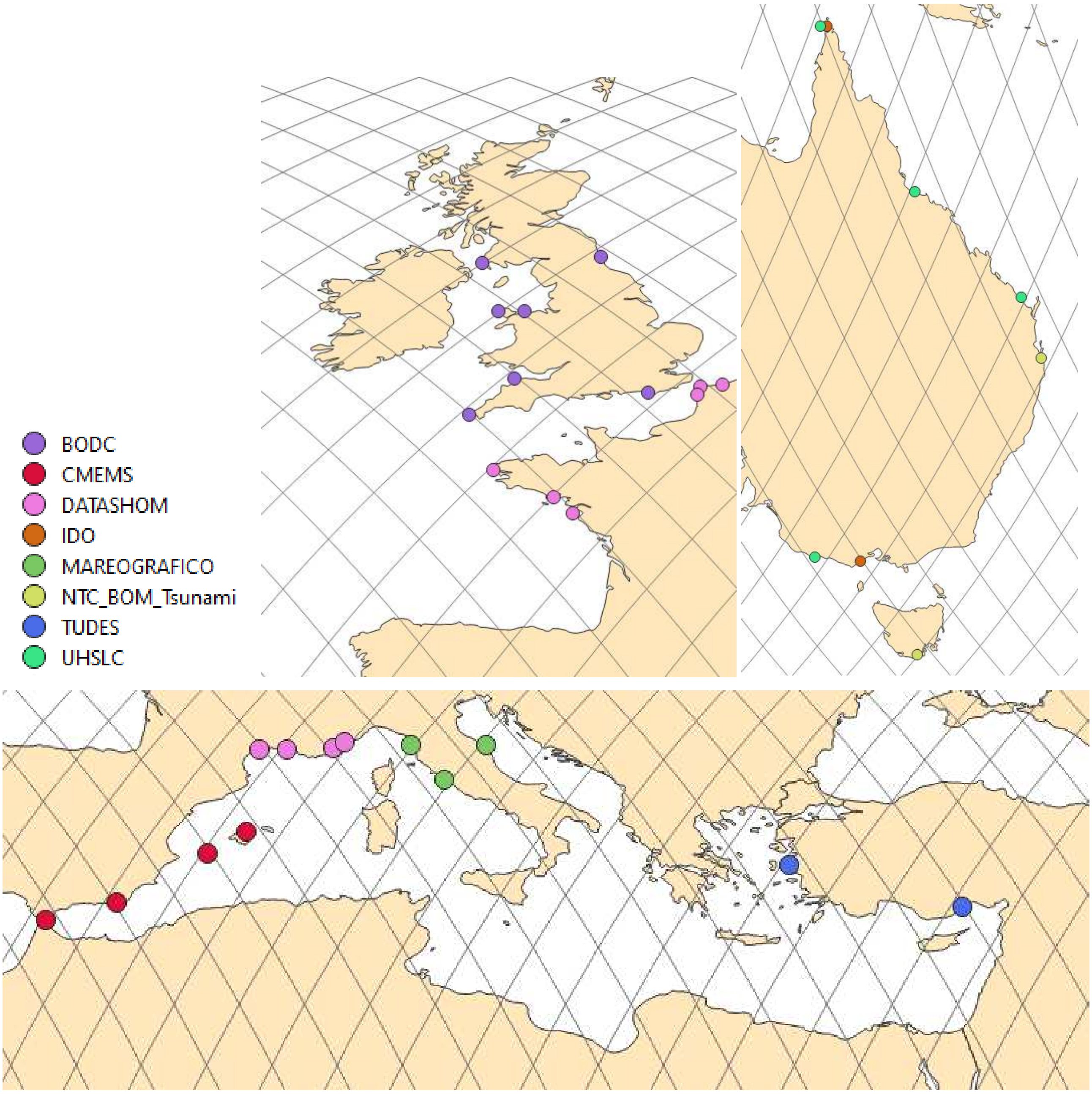

Figure 22: Location of the selected tide gauge stations for the SLA products validation in Australia, North East Atlantic and Mediterranean Sea. The grey lines represent the Jason-2/3 tracks.

The times series from the selected tide gauge stations were checked so as to remove suspicious points and then perform the harmonic analysis to extract the tidal signal. By subtracting this signal to the total tide gauge elevation time series, we obtained the de-tided elevations that were then provided to the CTOH team for their exploitation in the comparison with the altimetry data.

4. Conclusions

The work performed by NOVELTIS within this study enabled to:

- Pre-select a reduced number of tidal models (global and regional) for the round-robin exercise performed by the Coastal Altimetry Working Group on the coastal altimetry corrections and parameters;
- Identify, verify and process a tide gauge database for the comparison with the coastal altimetry products generated within the round robin, in the three regions of interest.