Authors answers to RC1 comments/questions/recommandations

(for commodity reasons, we have reproduced the reviewer text in black, answers are in light blue, further action to the revised manuscript in bold blue)

The manuscript explains improvements achieved in FES2014b compared to its previously released versions. The FES global hydrodynamic ocean tide models have been a 'gold' standard of physics-based finite-element computational regime for the oceanography, geodetic, geophysical and other community, for a variety of applications and scientific research. The methodology for the model development is clearly and concisely described, without overburdening the reading with well-established theoretical background, which is already readily available in the cited literature. However, whilewe understand the convenience to synthesize the overall communication, we expected to see additional details in several sections to better assess the presented results. In addition, we urge revising for grammar, presentation and descriptions in figures, and re-working the abstract to include general details found in subsequent sections. In sum, we recommend its publication provided that the authors adequately address the general and specific comments

Specific Comments:

1. Can the authors concisely explain why this new ocean tide model is named FES2014b? We understand that may be there is an upcoming FES2022 (?) model, it would be good if the authors explain the historic, current and future development of this very unique global hydrodynamic ocean tide modeling, for the benefit of interested users.
The FES atlas series has started with the FES94 release, quickly followed with the FES95 one, which includes some upgrades and fixes for various issues detected after the FES94 official release. A similar scenario occurred for the FES98 and FES99, FES2002 and FES2004, FES2012 and FES2014 atlases production. Despite intensive quality checking during production phase, any new major version of FES atlas release is followed by an extended verification/validation phase from the FES team and other world-spread specialists through the science applications that used the new atlas. The upgrading/fixing step is limited to issues that do not demand any major changes in the production process (such as unstructured grid modifications) but still will bring valuable improvements for the final user.
This is also requesting to more clearly delineate FES models 2014, 2014b, 2014c, e.g., for clearly recommending to the users which model should they use?
The FES2014a atlas is an intermediary step, which was only released for the need of performances assessments by the tidal community (using GOT LSA). A new loading and self-attraction atlas has been computed from the FES2014a release, and use to generate the FES2014b release (instead of GOT LSA). The FES2014b is the official project release, and should have remained the last one. However, to provide a more comprehensive, coherent tidal spectrum for tidal predictions particularly for the geodesic community, several long period tides constituents were explicitly added (computed from mass-conservative equilibrium solutions) to the FES2014b atlas. It must be noticed that similar long period constituents are implicitly added in tidal prediction if no external solution file provided. The extended atlas has been named as FES2014c to avoid confusion.

2. The abstract overemphasizes the improvement of the new model from its previous releases. It is ok to highlight this in one or two lines, but please also include summarized details of each main section.
It will be done in the revised manuscript.

3. Abstract. Define ITRF; however, the authors may have meant IERS Standards, 2010? If so, please also define IERS and others in the manuscript as appropriate. For example, AVISO+, LEGOS, T-UGOm, CEFMO, LGP1/2, NCP1, GEBCO, ETOPO, RTOPO1, etc.
It will be done in the revised manuscript.

4. We note that various bathymetry models, including the one inverted using satellite radar altimetry (Sandwell & Smith). Can the authors comment on the applicability of the satellite inverted bathymetric model which would not be sensitive to the gravity signals resulting from coastal sediment compaction and loading?
The authors are fully aware of inverted bathymetry issues on shelves and coastal regions, and consequently were not used in such locations except in some specific areas, in absence of any other more accurate bathymetry. It must be noticed the latest GEBCO distributions now include patches coming from inverted bathymetries, which is a serious issue for using recent GEBCO distributions in FES model bathymetry.
It would be great if the authors could characterize, approximately, the impact of the state of the art bathymetry model on coastal ocean tide modeling. For example, for the FES model is the bathymetry model accuracy still the limiting error, or other errors sources, in the state of the coastal ocean tide modeling?

Bathymetry still remains unfortunately the limiting error to our prior hydrodynamic solutions in most of the global ocean, and also impact the data assimilation accuracy in shallow waters regions. For most of Northern American, European and Japanese waters, this not so much the case. For instance, thanks to the impressively accurate new bathymetry of the European shelf (as available through EMODNET products), most of errors due to bathymetry have dramatically reduced, so we could clearly demonstrate that a wetting/drying scheme is necessary to reach the best tidal accuracy in the North Sea. Using more ancient bathymetry would have totally blurred this point, making any conclusions uncertain.

5. Along the lines with the good discussions of S2, K1 aliasing (dependent on different altimeter data in the tidal solution), please discuss the issue of S1, and also may be pole tides?
The astronomical part of S1 is rather negligible, and it is mostly forced by the atmosphere, which shows significant seasonal and inter-annual variability. So any harmonic S1 solution will be the reflect of the mean of S1 tide over a given time period, and would need to be completed with a consistent residual S1 DAC correction to account for its intrinsic variability. However this intrinsic variability is rather weak, and the accuracy of the S1 DAC solution is still limited by the temporal resolution of the atmospheric forcing used today. So at present, the operational processing of GDRs data is based on a DAC corrected from the mean S1 and S2 atmospheric components, and the S1 S2 variability (both atmospheric and gravitational forced) is then removed by the S1 S2 tidal model. So when the atmospheric forcing will allow sufficient accuracy for the S1 DAC processing, the FES group would be in favor of leaving S1 correction to be accounted for in the high frequency storm surge correction (DAC) instead in the tidal correction.
About pole tides, they are not targeted in the FES tidal atlases (which are mostly focused on higher frequencies), and are available from others sources (such as Wahr, 1985 https://doi.org/0.1029/JB090iB11p09363).

6. Section 3.2: Removing the entire Sa and SSa constituents, or just the non-tidal contribution in Sa and SSa? Please clarify. Also further elaborate on GLORYS-v1.
The correction with GLORYS-v1 SSH (Mercator-Ocean re-analysis) at annual and semi-annual periods aims to remove as much as feasible non-tidal contributions in sea level anomalies that could pollute K1 extraction from altimetry observations.
GLORYS produces and distributes global ocean reanalyses at eddy-permitting (1/4°) resolution that aim to describe the mean and time-varying state of the ocean circulation, including a part of the mesoscale eddy field, over recent past decades with a focus on the period since when satellite altimetry measurements of sea level provide reliable information on ocean eddies (i.e. from 1993 to present). The numerical model used is the NEMO OGCM in the ORCA025 configuration developed within DRAKKAR consortium (global with sea-ice, 1/4° Mercator grid). The model surface boundary conditions are derived from atmospheric ECMWF reanalyses. Assimilated observations are in-situ T&S profiles, satellite SST and along track sea-level anomalies obtained from satellite altimetry. The data assimilation method is based on a reduced order Kalman filter using the SEEK formulation. GLORYS-v1 re-analysis is obtained by assimilating data (including altimetry SLA) into NEMO.

7. Section 3.4: Explains the ice coverage problem in high latitudes. It seems that this section only applies to unbalanced observations caused by ice coverage and not other phenomena affecting the tidal estimates e.g. ocean circulation. This is explained in section 3.2 and in section 4.3 where fewer crossover data were added for the data assimilation process because of the large contamination of mesoscale processes. Please consider adding these effects (or others), affecting the separability and possibly state their impact on the extended frequencies in the FES2014b model version.
The presence of seasonal ice induces a possibly large loss of data in the polar oceans. In this case, the usual Rayleigh criterion, based on observation duration, will fail to accurately estimate frequency separability. The principle of our separation diagnostic method is more direct. Ideally, i.e. in case of quasi-infinite time series, the harmonic matrix will be quasi-diagonal. The shorter the time series, the larger the cross-terms/diagonal-terms ratio in the matrix, which reflects the loss in separation efficiency. In the case of a regularly sampled, continuous time series (no data missing), the usual Rayleigh criterion (at least 1 period difference between two different constituents over the time series duration) is equivalent to a maximum ratio of ~0.15 in any row of the harmonic matrix. In the case where 2 constituents show a ratio larger than 0.15, we check whether admittance can be used to infer the one with the lowest astronomical potential or not. If not the case or if at least one is a non-astronomical constituent, we drop it.

8. Figure 2-3: The details at some regions lost at the coastal regions for both the upper panel and lower panel. Consider an alternate symbology for the presentation of vector differences.
It will be done in the revised manuscript.

9. Figure 11: Add source for tide gauge database and each of the respective data count.
It will be done in the revised manuscript.

10. Related to above on pelagic tide gauge data validation of tide models. Can you comment or would you have cases where the tide gauge data used to initialize/constrain FES model are used and not used to evaluate the FES model?
Unfortunately, the number of quality tide gauge data is not large enough to allow for a distinct data assimilation and well-balanced validation datasets. In consequence, we made the choice to use the same quality-checked dataset for both use. So there is a bias in terms of accuracy when comparing our final solution with the assimilated dataset. However, because of the ensemble/data representers approach, the assimilation solution will not easily fit the tide gauge data if not consistent with model error covariance or altimetry data. Internally, we also make consistency checks by assimilating altimetry data only, then comparing with tide gauge data and reverse.

11. Figure 16: A slight rise in variance is visible around Lapdev and Kara Seas for Altika mission altimeter data, when using FES2014 and FES2012 models as tidal corrections. Speculate on the reasons for such a rise in variance.
The Altika mission suffers from shorter (in duration) and fewer (in repetitivity) exact repeat observations compared to Jason time series. In consequence, the variance reduction diagnostic is therefore made on a less significant statistical basis, and the overall variance reduction map shows many local, “noisy” outliers (compared to the surrounding general tendency). In addition, seasonal ice in the Arctic Sea is furthermore diminishing the number of available valid observations, hence potentially increasing the uncertainty on the variance reduction estimates. Some independent validation was performed to compare FES2012 and FES2014 (by R. Ray in particular) and showed the clear improvement in FES2014. So we tend to consider that the rise shown in the Altika comparison might not reflect a lower FES2014 accuracy in this region, but simply a statistical issue. Unfortunately, the lack of reliable tide gauge dataset for the Kara and Laptev Sea makes any stronger conclusions quite difficult to draw.