Ocean Science
Discussions

Interactive comment on "FES2014 global ocean tides atlas: design and performances" *by* Florent H. Lyard et al.

Edward Zaron (Referee)

edward.d.zaron@oregonstate.edu

Review of OS-2020-96 by Lyard et al

This paper provides a thorough description and evaluation of the FES2014 tide model, in several variations. The rationale and design of the modeling and assimilation strategy for developing FES versions is explained very clearly, and the detailed description of their ensemble technique will be a welcome addiiton to the literature. This information will help ocean modelers understand the potential strengths and weaknesses of a model like this, and it will also guide others hoping to build on their work in the future. The detailed evaluations of the model and comparisons of its various versions and other tide models will be useful to potential end-users of the tidal atlas. I believe this

article will be of interest to readers of Ocean Science Discussions, and I recommend that it be published after some minor revisions, detailed below.

There are two main areas where the article should be revised to make it easier for a reader to understand and use the provided information:

1) In some places the article lacks clarity regarding the rationale for the comparisons using FES2014a, FES2014b, and FES2014c. Examples are noted in the detailed listing below. The manuscript would be a little easier to read if it clearly stated ahead of time which versions of the atlas are being used and why.

2) The article does not discuss at all the tidal prediction software which is provided with FES2014. I don't think that the article needs to discuss or provide this in detail, but it needs to be clearer about the nature of the tidal predictions used for computing variance reduction statistics. Do these predictions include all the tidal frequencies mentioned in the manuscript, including the ones which are forced with the ERA-interim in the time-stepped model? Do the predictions include smaller tides computed using inference? If so, do the inference formulas rely exclusively on those tides which were computed with assimilation, or do they use some of the other frequencies?

If the comparisons of different models use different constituents, then the manuscript should state this clearly in the tables or figures where the comparisons are shown.

Another aspect of the tide predictions needs to be discussed since the atlas is intended for correcting altimetry: How should FES2014 be used when a separate model is used to provide a DAC?

Detailed comments:

Good introduction which lays out the features of the tidal data assimilation: limitations of L2-norm, hence importance of the prior model and outlier rejection, and relative data sparsity depends on dynamics/wavelength.

Good explanation of FES2014a, b, and c releases.

p5,l7-9: "Initially, ... integrated in ..." I don't understand this sentence.

p5,l33: Does the discrete system satisfy any conservation laws?

p5,l35: Thus, there is no lateral eddy viscosity in the model?

p7,l8-9: "even at regional extents, as earlier ... compensation bias." I don't understand this part of the sentence.

p9,l8-9: Are you making a distinction between the tidal loading (the deformation of the earth surface caused by the tidal changes in ocean bottom pressure) and the solid earth tide here (the deformation of the earth surface caused by the gravitational perturbations of the sun and moon)?

p9,l30: Thanks for describing this in detail.

p9,l36: I would have expected that all the harmonic analyses were based on the longest records available, so this section on S2 can probably be deleted.

p10,l19: Please explain this procedure more precisely. Is this equivalent to computing the standard error matrix for the least squares solution, and then recomputing estimates for fewer frequencies when the error correlation was too large? Exactly what criterion was used?

p10,l33: This is a little confusing. Are you saying that there are a total of N_{tot}=432 ensemble members, and these are computed from sets of indepdently perturbed ensemble components? Do you have, $N_{tot}=N_{bottom\ drag} * N_{internal\ tide} * N_{bathymetry} * N_{LSA}$ where $N_{LSA} = 2$, corresponding to the FES99 and FES2012 load tides?

(I see, yes. Made this table while reading later:)

$N_{bottom\ drag} = 8 * 13 = 104$

$N_{internal\ tide} = 10 * 7 = 70$

$N_{bathymetry} = 2 * 18 + 6 = 42$

p13,l6: "SpEnOI code is solving the assimilation in the data space" – Are you aware that you could reduce the dimensionality to 432 by solving in the space spanned by the ensemble members, without reducing the quantity of data at all?

p13,l7-22: Can you reduce this text and just state what data you used for assimilation versus validation? I don't understand what data were used.

p13,l30: Did you use an estimate of the data error to weight the datasets that were assimilated, or did you simply assimilate fewer data in the noisier regions?

p14,l23: Could you please make clear whether "FES2014" refers exclusively to FES2014c in this section, or if you are describing aspects of the FES2014a and b solutions, too.

p14,l29: Earlier you stated that S1 belongs to the DAC solution. Please clarify.

p14,l40: I am confused about the use of ERA-INTERIM atmoshperic forcing. Wouldn't you want to compute purely gravitationally-forced versions of these, since the atmospherically-forced component would be provided by a separate DAC model? Since the goal of the paper mentions developing the tidal atlas specifically for de-aliasing altimetry data, you should be clearer about how this should be done in practice using FES2014c, since there is the potential to unintentionally duplicate corrections from the tidal atlas and the DAC correction as it is usually applied.

p15,l30: Could yoiu please remind us about why you are validating FES2014b instead of FES2014c here?

p15,l36: Does "TPXO9" refer to the "TPXO9v2" mentioned on page 14? And, does "TPXO9-atlas" also refer to "TPXO9v2"?

p16: I am unclear on why FES2014a and FES2014b and FES2012 are used in some of these comparisons. I understand if this is simply related to the reporting of comparisons

originally conducted for various purposes, but perhaps you could mention the reasons at the beginning of this section.

p17,l31: Can you cite a source for this statement? This certainly depends on depth of the station, stratification, etc.

p18,l28: "dynamical quasi-coherence of the covariances" – I don't know what this means. Please explain or omit.

p18,l30: Can you say anything about the results of Fig 21? If they don't show anything new, then perhaps this section can be omitted. Alternately, maybe they basically confirm but slightly alter previous estimates. Or maybe there is something that can be gleaned from comparisons of recent calculations by DeLavergne et al. Since you previously stated that the currents are not reliable in regions of steep topographic slope (line 13), why would the energy flux divergence or the parameterized baroclinic wave drag be reliable?

p19,l26: "After proper, competitive evaluation procedures" – Without explanation, the reader is not going to know what you are referring to. Could you either omit this phrase, provide a citation, or explain this topic further?

English usage/typos:

p5,l5: omit "about a"

p5,l42: "it is known to allow for" –> "that it allows"

p6,l7: "multi-levels" –> "multi-level"

p6,l10: I am more accustomed to seeing "CFL" rather than "CLF" for this abbreviation.

p6,l16: omit "and"

p6,l27: "Go" –> "GB" ?

p7,l18: "SAL" –> "LSA"; and fix "atlas atlases"

p7,l42: Why repeating S1 in the parens?

p7,l38: Can you reorganize this paragraph for clarity? Something like:

"The hydrodynamic solution for the S2 tide differs from the other tides in that the atmospheric forcing is explicitly included. ... The S1 tide originates mostly from the atmospheric forcing, and it was therefore not computed in the hydrodynamic tidal solution. ..."

p8,l16: omit comma at the end

p9,l14: please fix "Then,18); this"

p9,l20: I thought Parcel's theorem was the equality of the sum of squared Fourier components with the variance. Please reword or explain . p9,23: "guaranty" –> "guarantee"

p10,l11-12: omit "to ease the harmonic system solving"

p11,l8: ", 1982" –> "(1982)"

p11,l14: "abuse" –> "abuse of nomenclature"?

p11,l18: "is run" –> "are run"

p11,l21: "tide drag" –> "internal tide drag"?

p12,l6: "sloppy" –> "sloped"

p12,l9: "efficiency is strongly dependent on" –> "depends on"

p12,l13: "(75)" ?

p12,l19: commas after "GEBCO" and "release"

p14,l6: "repartition" –> "distribution"

p14,l16: "it small" –> "its small"

p14,l17: "ration" –> "ratio"

p16,l9: "if" –> "while" or omit "if"

p16,l14: "none data" –> "none of these data" or "no data"

p16,l11: Presumably, you used all the tidal harmonics available from each model in these comparisons, since you mentioned errors of omission previously. You should remind the reader of this here, or later in the Discussion.

p16,l20: Can you redo this comparison of FES2014a with FES2014b, instead? p17,l40: repetitive of line 34; please consider revising this entire section for brevity.

p18,l15: omit "Somehow,"

p18,l37: capitalize "Love"?

p18,l39: omit "then derivation"?

p19,l23: "others" –> "other"

p19,l35: "coastal details grid flexibility" –> "detailed coastal grid"

p19,l38: omit "generation"

p20,l5: "atlases" –> "atlas"; omit "locally strongly" on l6

p20,l9: "eased" –> "open"

p20,l11: "as well in terms of" –> "for both"

Figures and Tables:

p24-25,F2 and F3: The caption mentions panels a, b, and c, but only two panels are shown. Pleas label the panels a, b, and c, and include the Darwin name boldly somewhere on each plot.

F4: capitalize "Maps" in caption. Other captions also need this correction.

F8: The figure shows that the bathymetry of Weddell sea was perturbed, but I thought

the text mentions that, after initial experimentation, it was not.

F12: Please clarify how "deep", "shelf", and "coastal" are defined. Is it a depth criterion, or simply whatever the data source happened to label it as.

F13: I cannot distinguish the dark colors at the ends of the colorscale. Maybe represent this data with different size disks, like your previous comparisons in Fig 2? It is difficult to understand the information on this map.

F14: Consider coloring the land and sea differently (white vs light gray). Does blue mean that FES reduces more variance?

F15: Is this comparing tide predictions made with the same constituents from each model? If not, you should explain to the reader that FES is providing more constituents, and/or cite Stammer et al, or Zaron and Elipot (2020, https://doi.org/10.1175/JPO-D-20-0089.1) where the comparisons are restricted to common constituents.

F17: Once again, it is important to be sure the reader is aware whether the same constituents are being used, especially since FES2014 is using a number of frequencies with substantial atmospheric forcing. Also – GOT is not really intended for use close to the coastline. Did you extrapolate the values landward, or does this comparison only use locations where GOT grid cells happen to overlap the coastline?

F18: I think this figure can be omitted.

F20: Can you use a different scaling to make the current ellipses more visible? Consider omitting this figure if you can't revise it. Or, maybe show a few representative comparisons enlarged, instead.

F23: The caption is hard to understand. Could you describe this with something like: "Map of the SSH variance difference a crossovers using the FES2014a tidal loading versus the GOT4v8ac tidal loading. ..."

p39,T1: fragment at end of caption, "3 Tidal harmonic ..."

p39,T2: Please fix "#DIV/0!". Also the different vertical alignments and number significant figures displayed for values in the table is disconcerting. Also, unlike the other numeric values in the manuscript (cf., Table 3), the "," is used instead of the "." to indicate the decimal point; please revise for consistency.

p40,T4: What criteria are used to distinguish "shelves", "Open ocean", and "Arctic Ocean"? Is the Max error criterion applied to the least-squares error estimate (from the harmonic analysis), or do you estimate the error in some other manner?

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