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Comment on se-2021-151

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Community comment on "Regional mantle viscosity constraints for North America reveal upper mantle strength differences across the continent" by Anthony Osei Tutu and Christopher Harig, Solid Earth Discuss., <https://doi.org/10.5194/se-2021-151-CC1>, 2022

Dear Editor,

The manuscript "Regional mantle viscosity constraints for North America reveal upper mantle strength differences across the continent" by Osei Tutu & Harig investigates the regional mantle viscosity values for North America using a local Bayesian joint inversion of mantle flow and GIA models. They use the region free-air gravity data and RSL data. The topic is interesting and worth studying since North America is a key region to deduce the mantle viscosity structure and to better understand the solid Earth behavior due to the loading and unloading of the Laurentide ice sheet.

The figures are of good quality and easy to read. However, several aspects of this manuscript need to be improved/addressed before it can be considered for publication in Solid Earth.

In this study, the RSL database from Tushingham and Peltier (1991) is used, which is pretty old and outdated. There are more recent high-quality standardized RSL databases for eastern Canadian coast (Vacchi et al., 2018), including Hudson Bay, U.S. Atlantic coast (Engelhart & Horton, 2012), Pacific coast (Engelhart et al., 2015), and they are all freely available. Why don't you use the recent ones? The importance of the standardization of RSL data has been demonstrated in many studies, especially for the differentiation of sea-level index points (SLIPs) and limiting data, which are not considered in Tushingham and Peltier (1991). Moreover, your eastern region () includes U.S. Atlantic coast, but no RSL data from the Atlantic coast of NA, which have been shown to be vital to constrain the viscosity and may result in totally different upper mantle viscosity values as that from Hudson Bay (e.g., Engelhart et al., 2011).

Why restrict ice melting history and RSL data to < 10 kyr BP (line 142)? What's the significance behind this? Does that mean you only have a deglaciation stage from 10 ka BP till present but no glaciation stage in your GIA ice model? You cannot only use ice melting < 10 kyr BP to even only study the RSL < 10 ka BP. Because the solid Earth response to loading/glaciation and unloading/deglaciation events is a delayed process, what happened before 10 kyr BP (e.g., the LGM) definitely significantly affect the RSL <10kyr BP.

Line 244-245, "differences in our inferred 1D regional ..." and as you stated in the abstract, this means the uncertainty of inferred 1D regional viscosity due to the uncertainty of scaling factor is significantly dramatic, then comes the question about the validity and accuracy of this approach to infer the 1D regional viscosity. In that case, you need to assess the uncertainty of the inferred viscosity.

Whole North America, eastern sub-region, western sub-region, you need to follow the same order through the whole paper for each section. Besides, suggest you consistently using "sub-region" when refer to western and eastern North America region, as you used in line 197. Please consistently use the same expression for the seismic velocity to density scaling parameter.

The usage of abbreviation and full name in this manuscript is really in chaos, like relative sea level (e.g., line 137, 163, 403) and RSL (e.g., line 44, 139, 299), North America (e.g., 83, 191, 256) and NA (e.g., line 18, 55, 98), glacial isostatic adjustment (e.g., line 189, 416) and GIA (e.g., line 23, 36) ... Also misuse of italic for some common words, like *localized* in line 104, *volume* in line 106,

Citation formats in the main text need to be double checked.

Detailed comments:

1, Replace the word "strength" in the title, maybe by "viscosity", as "strength" only appears once in the title and then never been used any more in the main text.

2, Line 6, replace "North America" with "NA".

3, Line 26, I don't see any paper you cited in lines 23-25 that investigates 3D GIA. There

are some recent 3D GIA papers in North America, e.g., Clark et al. (2019), Kuchar et al. (2019), Li et al. (2018, 2020), Li & Wu (2019).

4, Line 42, for the refs, should be "James et al., 2009a, b" and "Yousefi et al., 2018, 2021".

5, Line 44, change "constraints" to "constrain". And "testing different RSL curves" doesn't make sense, please rephrase.

6, Line 49-50, the sentence "using only ..." doesn't make sense, please rephrase. It is the viscosity values that constrained by postglacial rebound data only with GIA modelling and viscosity values that revealed by mantle flow modelling have some differences.

7, Line 53, delete the "North America", you have used the abbreviation "NA" in line 18 for the first time.

8, Line 56, why the two "local" here are italic? Any special indication?

9, Line 104, 106, why keep using italic "localized" "volume" for some usual words?

10, Line 126, delete "a" and add "model" after GIA.

11, Line 133, I doubt you can use "ice thickness datasets" here, better change to "models"; use "ICE-6G_C" to be consistent with the original paper Peltier et al. (2015).

12, Line 134, delete "North America", as you used "Laurentide" already, use "component".

13, Line 137, change to "and compare the modeled RSL predictions against RSL data using a misfit function". Model outputs are predictions, not data. Besides, better to use RSL abbreviation as it is used dozens of times in the paper. Especially you are using NRSL data to calculate the misfit statistics, the old database doesn't have a clear differentiation of sea level index point and marine/terrestrial limiting data, which will affect your misfit calculation.

14, Line 140, delete "as shown in".

15, Line 150, move "to take advantage ..." to the beginning of the sentence and change to "Due to increasing availability and declining expense of computing resources,".

16, Line 153 delete "modeled-" if you are referring to observational data, or change "modeled-observation data" to "model prediction" if you are referring to prediction.

17, Fig. 2, there is no label for Fig. b-d.

18, Line 189, add "described" before "above".

19, Line 192, change "east-west continental divide" to "east-west continental sub-regions"

20, Line 193, need refs after "3D finite element or finite volume GIA modeling". What does "these authors" refer to?

21, Line 196, change to "We explore the lateral changes in upper mantle viscosity structures between the eastern cratonic and western region with our joint inversion."

22, Line 222, add "of" after "a series".

23, Line 223, change "based in" to "based on".

24, Line 238, delete the "a" before "weaker".

25, Line 239, change to "with the depth-dependent seismic-to-density parameter scaling profile from Simmons et al. (2010)."

26, Line 241, change "that in total results in" to "which is".

27, Line 243, change "strong" to "high", the viscosity values can be high or low, cannot use "strong".

28, Line 256, change "east and west regions" to "east and west sub-regions", as you used in line 197.

29, Fig. 4a-d, why the title is "Western shallow lithosphere" and "East cratonic lithosphere"? Where does the "lithosphere" come from? Shouldn't it be something like "Western sub-region" and "Eastern sub-region"?

30, Line 265, change the sentence "This aligns ..." to be more conservative (e.g., might be correspond with ...), as they show notable differences (410 km, 250-350 km).

31, Line 267, change "gave" to "gives" to be consistent with the rest regarding the grammatical tense.

32, Fig. 5b-c, where is the "GLAC-ICE" from? You use "GLAC1D-NA" in the main text, do you mean the same one? Besides, for Fig. b, please use the same line color but different line style for the ice model results, just like Fig. c

33, Line 299, you refer to Fig. 7 before Fig. 6, please reorder the figures to match where they are referred in the main text.

34, Line 298-301, Fig. 7 shows two results that used the Simmons et al. (2010) seismic conversion profile, why here you compare the solid lines with the dashed lines (using constant conversion parameter of 0.3) in Fig. 5b? The whole sentence doesn't support your point.

35, Line 310, change "a weighting the" to "a weighting of", move the "(i.e., $\alpha = 1$)" in line 314 to the end of "those have no weighting applied". Line 310-313, the first two sentences tell the same thing, please combine and only keep one sentence. Moreover, add one sentence before "The most obvious impact ..." to explain what it means by changing alpha from 1 to 2, double the weight of GIA data in constraining the viscosity? If yes, the viscosity values constrained by higher weight of GIA data should be closer to the results derived by GIA modelling.

36, Line 318, change "with (Simmons et al., 2010) seismic-" to "with Simmons et al. (2010) seismic-".

37, Fig. 6a-b, why the title is "Western shallow lithosphere" and "East cratonic

lithosphere"? Where does the "lithosphere" come from? Shouldn't be something like "Western sub-region" and "Eastern sub-region"? In the text in line 318 and line 329, you say using Simmons et al. (2010) scaling, while in the figure caption, you say using constant scaling of 0.3, which is correct?

38, Line 322-323, the citation should be "James et al., 2000, 2009a, b", there is no Fig. 6d but you refer to Fig. 6d. Line 324, change "larger" to "large", change "regions" to "regional".

39, Fig. 7, change the shades to be slightly transparent, now cannot distinguish the overlay zone of blue and dark grey shades. The error bars are for 1σ or 2σ ? Please make it clear. The deep blue and deep black solid lines are referring to average viscosity profile results? Please add description.

40, Fig. 8, the ICE-6G-Na is not included in the caption. Alternatively, you could shorten the caption as "Similar as Fig. 7, but joint inversion is based on $d\ln\rho/d\ln v_s = 0.3$." Fig. 8 is not mentioned in the text.

41, Line 338, the second "e.g.," should be before the citation. Line 339, should be "geodynamic" not "geodynamics".

42, Line 340-341, a channel needs the viscosity value to be lower or higher than both the upper and lower parts, which is true for Fig. 3a & d for the asthenosphere and transition zone, but not the case for Fig. 3b & e. Please revise the sentence.

43, Line 362-364, add a "," before "we inferred", add ", which" after "in the transition zone". Line 367, for the "moderately weak channel", do you indicate upper mantle? As upper mantle has a relatively weaker viscosity in Fig. 3b & e, Fig. 4a & b, Fig. 5, and Fig. 6a. If yes, change "weak channel" to "upper mantle".

44, Line 391, add "sub-region" after "east-west"

45, Line 431, Fig. 9 is for the western NA sub-region, do you mean Fig. 7?

46, Line 432, the resulting upper mantle viscosity of $\sim 10^{22}$ Pa s (Fig. 6b) might be related your thin lithosphere around the Hudson Bay. All your RSL data in the eastern NA sub-region are from Hudson Bay, while previous studies (e.g., Wang & Wu, 2006) showed that the lithospheric thickness around Hudson Bay is around 200 km. You can add some

explanation here on this point.

47, Line 463-464, for the last sentence "Our results also show ...", I don't know see the evidence in the main text to show this statement, you can rephrase as "Our results imply the potential need to consider lateral variation of mantle seismic ..."

48, Fig. A4, all the predictions and RSL data are compressed horizontally/temporally compared with other plots (e.g., Fig.7), please double check.

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