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Interactive comment on "The imprint of crustal density heterogeneities on regional seismic wave propagation" *by* Agnieszka Plonka et al.

Anonymous Referee #1

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This manuscript entitled "The imprint of crustal density heterogeneities on seismic wave propagation" by A. Plonka et al. has some very fine insights and I have carefully read it. The manuscript presented a series of numerical experiments to study the effects of density heterogeneities on regional seismic wave propagation in terms of traveltimes and amplitudes, at different frequency bands, different epicentral distances, and with different medium complexities. Those experiments provides important implications for tomographic inversions, in which density variations are rarely discussed. However, there exist some issues and ambiguities in the paper required to be further elaborated. Overall, the manuscript can be published in Solid Earth upon minor revision. I'll explain in more detail below.

1 Specific comments and technical corrections

1. Page 5 part 15, please provide details for the moving window $w(t)$, including shapes of window function, width, moving interval etc. Did you adapt the resolution of $w(t)$ at different frequency band? Take wavelet transform for example, at high frequencies, narrow basis functions are used, and the moving (shift) offset also depends on scales.

2. When I read "2.2 Random media generation", I had a lot of questions on how the random media are generated by combing tomographic models and empirical velocity-density relations. How rms from tomographic models is used to constrain random model generation. Did you use the ranges from tomographic models? etc. However, "4.2 Random models of plausible Earth structure" provides much more details on those questions. To help readers better understand the generation of random models, I would recommend the authors show those details earlier, instead of waiting till the final discussion.

3. Page 5 equation (3), a recommended way to evaluate amplitude difference is to first shift $\hat{u}_\tau(t)$ by $\delta T(\tau)$ estimated in equation (2), then compare the amplitude difference of shifted $\hat{u}_\tau(t)$ and $\hat{u}_\tau^{ref}(t)$. Is $\ln(\delta A(t))$ a better quantifier for amplitude difference than $\delta A(t)$?

4. Page 6 part 10, move the sentence "Before attempting a more comprehensive analysis in the following sections..." before "Figure 3 shows a comparison of three-component...".

5. Page 6 part 15, in sentence "Relative amplitude differences are largest on the E-W and vertical components, where the displacement velocity itself is smallest so that the influence of scattered waves is largest", do you really want to say "Compared to the N-S component, relative amplitude differences are larger on the

E-W and vertical components, where the displacement velocity itself is smaller so that the influence of scattered waves is larger" ?

6. Page 6 part 15, in sentence "... meaning that amplitudes for the heterogeneous density crust can be both twice and half as large as for the medium with homogeneous crustal density" do you mean " either twice or half as large as ..."?

7. Page 7 part 30, misspell of "negative" .

8. Some suggestions on the structure of the document. It might be more compact to take "3.1 A single-receiver example" as a subsection of "3.2 The effect of frequency", which consists of two examples: a single-reviver, and all receivers.

9. It has been assumed that all random velocity and density models used in simulations are spatially uncorrelated. In reality this assumption is not valid and velocity density variations are correlated/scaled. Could the authors make comments on how the correlations would affect the conclusions?

10. Those numerical experiments left some thought-provoking implications for full-waveform inversion, which may be biased if density variations cannot be neglected. To consider density-induced waveform perturbations in tomographic inversion, one may need to distinguish the effects from velocity and density structure on waveforms, as well as their coupling effect. Even though different phases are not separated in the analysis in this paper, the authors should understand that the effect of density heterogeneities on different seismic phases might be different.

11. It may worth to discuss the work by *Yuan et al.* (2015), in which density variations are updated together with wavespeed in surface-wave full-waveform inversion to lessen the bias in wavespeed inversion caused by incorrect density variations.

12. To be clear, add t underneath $argmax$ in equation (2).

References

Yuan, Y. O., F. J. Simons, and E. Bozdağ, Multiscale adjoint tomography for surface and body waves, *Geophysics*, *80*(5), R281–R302, doi: 10.1190/GEO2014–0461.1, 2015.