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

**Anonymous Referee #2**

General comments:

Density anomalies within the Earth are known to have a poor imprint on seismograms. However, recent advances in FWI suggest that inverting this small imprint may be feasible. The present paper aims at investigating this feasibility by studying the imprint of density anomalies on seismograms through numerical experiments of wave propagation at the regional scale. The paper perfectly fits the scope of Solid Earth - Discussions. Its conclusions are supported by relevant figures, a well-written text and a clear organisation.

Specific comments:

You often talk about "medium complexity" (P1 L9, P3 L30, P6 L6, P6 L9...). It is not clear what you mean by that at first. Then we understand that it refers to the

correlation length of the heterogeneities: The smaller this length is, the more complex your medium is. I am not sure if "complexity" is the appropriate term here, because the number of parameters you need to define your random medium is the same in any case: it is just k_max (cf appendix A). I'd rather talk about "roughness" (in accordance to the term "smooth" that you introduce in P8 L20 as well as in the figure 9 captions). Whatever the name, you should define it much sooner in the paper.

The heterogeneities of density impact both the singly and the multiply scattered wavefields. FWI should be able to invert the singly scattered wavefield to recover density structures at the scale of the wavelength, but it cannot handle multiple scattering yet. You should state that more clearly in the abstract (P1 L12) as well as in the conclusion (P12 L32).

Fig. 3: From the last sentence of the captions, I understand that there is no cycle skipping on the Z-component coda, contrary to the NS and EW components. Could you explain why? This is really intriguing to me.

P9, L11-15 (from "One of those" to "larger zero peaks."): How these three sentences are related to the analysis you make in section 3.2? I am a bit confused here. Can you make this point clearer, please?

Noting that density is supposed to impact P and S energies in the same way (so that there is no need for any component rotation to look at a specific energy) could be valuable.

The two statements you make at the very end of the conclusion are reasonable. Nevertheless, be aware that the perturbations you observe in your computed seismograms have amplitudes comparable to the amplitude of a couple of seismic phases which are not modeled in regional simulations, such as PcP, PcS or ScS (see the figure below and some other examples in Cupillard et al, 2012, for instance). As a consequence, a particular care will be necessary for inverting small amplitudes in a given epicentral distance range using a regional wave simulator.

Technical corrections:

In many places in the text or in the figure captions, your write "from" before the value of a frequency band, like "frequency band from 0.02 - 0.04 Hz". That is really odd to me. I would either remove "from" or replace the dash sign by "to".

P2 L15: I'd specify "direct body wave" to implicitly notice that reflection data carry information about density.

P3 L1: Please update the reference to Koelemeijer et al, 2015

P3 L21: "represent a range of"

P 3 L29: "Scattering is most ... than the wavelength". Isn't it the definition of a scatterer? I would remove this part of the sentence.

P5 L6: "amplitude spectrum of these variations in the real Earth". I would add that to prevent any ambiguity.

Please interchange table 1 and table 2.

P7 L8-12: This is a little confusing to me. You just do the same measurements than before, working now on a 300s long window after the P-arrival to avoid cycle skips and low amplitude, right? I would remove "In line with ... surface and scattered waves"; it is useless; we perfectly got this point in the abstract and the introduction.

P7 L25: "for two out of five". Captions of figure 7 says "three out of five"!?!

P7 L28-33: "In the lower ... by $\sim$ 1 s." is a useless sentence; "Histograms for ... far-away stations" is too vague; I would remove these two sentences. I would also rephrase the following: "We examined the distance dependence further, using synthetic data from one of the numerical experiments contributing to the tail. We found that, for all the frequency bands, stations of epicentral distance between 1000 and 1200 km shows a mean time shift centred on negative values between $-0.08$ and $-0.14$ s. While this value is similar for..."

P12 L5: "0.125 Hz"

Appendix A: I would write phi(k) instead of phik. Moreover, you should mention that f(k) is flat below k_max.

Fig. 11: "0.125 Hz"

———————————————————
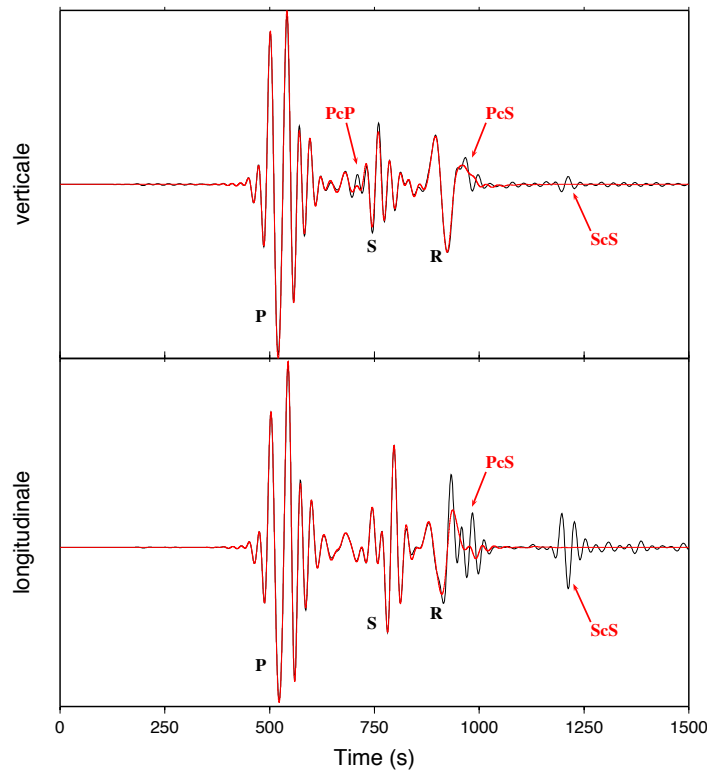
**Fig. 1.** Comparison between a regional (red) and a global (black) wave simulation within PREM. The source is an explosion at 150km. The receiver is about 3500km far from the source.