Solid Earth Discussions

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Comment on se-2021-16

Anonymous Referee #2

Referee comment on "Comparing global seismic tomography models using varimax principal component analysis" by Olivier de Viron et al., Solid Earth Discuss., https://doi.org/10.5194/se-2021-16-RC2, 2021

This manuscript applies principal component analysis (PCA) to identify and analyze patterns of structure found in global, seismic tomography models. The work presents a potentially useful tool to analyze commonalities and differences among the plethora of tomographic models that have been published over the years. The use of PCA to identify main patterns of velocity variations in tomographic models is not entirely new (see Ritsema and Lekic, 2020), and I think the reader would benefit from an explicit comparison of the differences and similarities between this and past work. Nevertheless, this manuscript is complementary to and moves beyond this previous work in that it redistributes the principal components in a manner that concentrates them in depth, using the varimax rotation. This is a clever and creative choice, which allows the method to identify patterns that can more directly be related to specific structures / target regions. Another interesting contribution is that the authors explore variations across tomographic models using a common set of PCs.

While a comparison of global tomographic models is a great place to start, I think the true power of this method might end up being in the analysis of local and regional tomographic models, which tend to use more diverse underlying datasets, and have highly variable spatial resolutions that could be revealed effectively by the type of PCA proposed here.

The authors point out that the number of PCs needed to explain nearly all (97.3%) of the variance in the tomographic models is always smaller than the number of splines / layers in the parameterization. Is this really surprising? After all, there is inherent smoothing of the retrieved structures due to both explicit regularization and data sensitivity. You write that “the splines or boxes seem to over-sample the available information” as if that is a bad thing. However, overparameterizing tomographic models and stabilizing the inversion through regularization has been advocated by some (e.g. Trampert and Snieder, 1996). It would be interesting to see which models and at what depths show largest differences between the underlying parameterization width and that of the PCs.

Doesn't the normalization applied to the velocity variations (standardization at each depth) skew the analysis toward the large mid-mantle areas in which velocity variations are quite small and often poorly resolved? Relatedly, the power in each component seems to be much smaller in this study than in Ritsema and Lekic (2020). Could this be because they did not normalize by depth?

The authors identify differences in the number of PCs that a required to compress tomographic models, and attribute them to differences in regularization. That is certainly a key parameter, but another difference among the models that is worth discussing pertains to what kind of data are included in the analysis. For example, if the model does not include constraints from overtones, structures in the transition zone and mid-mantle might not be well-retrieved. Treatment of discontinuity topography can also matter, because neglecting this topography can map directly into isotropic wavespeed variations in the mid-mantle.

I would prefer to see a summary figure of some kind, that synthesizes the information that is currently presented across many panels. I was keen to look at all the panels, but most readers might not be, and they would certainly appreciate a figure that eliminates the need for them to make comparisons between panels on their own. Overall, the number of figures/panels in this manuscript can be overwhelming.

I also had some minor questions and comments that the authors might wish to respond to and address:

- If the goal is compression, why use the varimax rotation? It is my understanding that the original PCs would always provide better compression.
- When discussing the patterns of heterogeneity, I kept thinking back to the term "heterosphere" introduced in Dziewonski et al. (2010) to describe the strong seismic heterogeneity in the tectonic uppermost 250km of global tomographic models.
- The 1D reference model for S362WMANI+M should be the STW105 model of Kustowski et al. 2008.
- When comparing countable quantities (like number of PCs), you should use the word "fewer" rather than "less", etc.