Targeted stacking of weak seismic phases for improving mantle discontinuity imaging using full-waveform inversion

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This study is a continuation of our efforts to connect adjoint methods and full-waveform inversion to common beamforming techniques, widely used and developed for signal enhancement. Our approach is focusing on seismic waves traveling in the Earth’s mantle, which are phases commonly used to image internal boundaries, being however quite difficult to observe in real data. The main goal is to accentuate precursor waves arriving in well-known times before some major phase. These waves generate from interactions with global discontinuities in the mantle, thus being the most sensitive seismic phases and therefore most suitable for better understanding of discontinuity seismic structure.

Our work is based on spectral-element wave propagation which allows us to compute exact synthetic waveforms and adjoint methods for the calculation of sensitivity kernels. These tools are the core of full-waveform inversion and by our efforts we aim to incorporate more parts of the waveform in such inversion schemes. We have shown that targeted stacking of good quality waveforms arriving from various directions highlights the weak precursor waves. It additionally makes their travelt ime finite frequency sensitivity prominent. This shows that we can benefit from using these techniques and exploit rather difficult parts of the seismogram. It was also shown that wave interference is not easily avoided, but coherent phases arriving before the main phase also stack well and show on the sensitivity kernels. This does not hamper the evaluation of waveforms, as in a misfit measurement process one can exploit more phases on the body wave parts of seismograms.

In this study, we go a step forward and present recent developments of the approach relating to the effects of noise and a real data experiment. Realistic noise is added to synthetic waveforms in order to assess the methodology in a more pragmatic scenario. The addition of noise shows that stacking of coherent seismic phases is still possible and the sensitivity kernels of their traveltimes are not largely distorted, the precursor waves contribute sufficiently to their travelt ime finite-frequency sensitivity kernels.

Using a well-located seismic array, we apply the method to real data and try to examine the possibilities of using non-ideal waveforms to perform imaging of the mantle discontinuity structure on the specific areas. In order to make the most out of the dense array configuration, we try subgroups of receivers for the targeted stacking and by moving along the array we aim at creating a cluster of stacks. The main idea is to use the subgroups as single receivers and create
an evaluation of seismic discontinuity structure using information from each stack belonging to a subgroup.
Ideally, we aim at improving the tomographic images of discontinuities of selected regions by exploiting weaker seismic waves, which are nonetheless very informative.