Full-waveform inversion for signal enhancement of seismic phases

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INTRODUCTION

A frequently encountered problem in seismology is dealing with weak wave phases which are oftentimes below noise levels. In many seismic tomographic problems there is need to use various body waves simultaneously in order to make the most out of the waveforms and extract information about earth structure at various depths and scales. However, the quality of recorded waveforms largely varies depending on the instrument but mainly on complex wave effects that can decrease the amplitude of a desired phase and place it below noise levels.

Our study aims at deploying linear stacking techniques to develop a misfit measurement that is appropriate for full-waveform inversion (FWI). Comparison is performed between two numerical Earth mantle models that cause waveform difference at specific low amplitude precursor phases, which represents an ideal test case.

METHOD

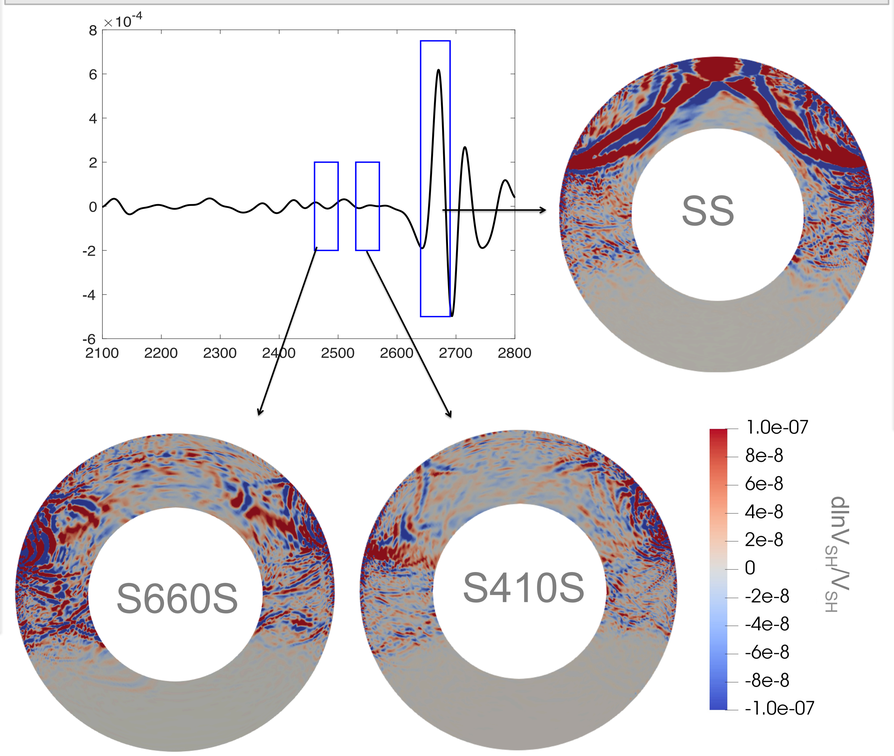
Calculation of synthetic seismograms

- SPECFEM3D synthetic seismograms.
- Synthetics are calculated in 1-D mantle velocity model
- '410' and '660' discontinuity topography is added.
- **Compare the effect of topo on the difference between stacked waveforms for each model**

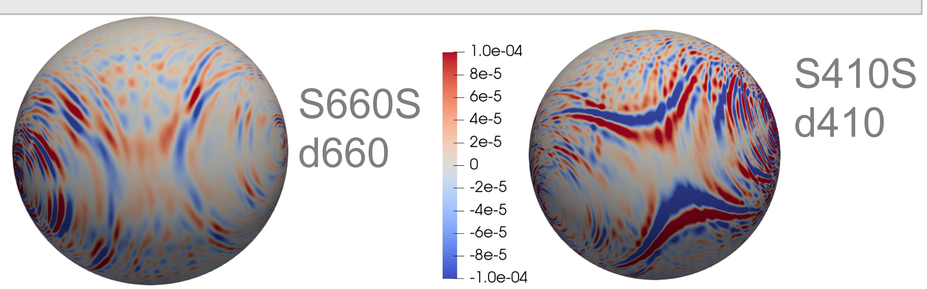
Calculation of time shifts:

- Select a receiver in the mid of the array as reference and align the other recordings to *SS* phase
- Stick to 1-D models for both the waveform stacking and kernel calculations.

V_{SH} volumetric kernels for traveltime in shown windows



Boundary kernels remain characteristic for SS precursors→ Structure on the surface is detectable although not accentuated with stacking



CREATING STACKS- 1-D

'Observed stack' **with topography**

$$u^{obs}(t) = \frac{1}{Nr}\sum_{i=1}^{Nr} u_o(x_{r_i}, t-\tau_i)$$

'Synthetic stack' **without topography**

$$u^{syn}(t) = \frac{1}{Nr}\sum_{i=1}^{Nr} u(x_{r_i}, t-\tau_i)$$

tau_i**: time shifts for each seismogram wrt the reference phase-used to align recordings**

THOUGHTS & OUTLOOK

✧ Weak phases of precursors remain weak when stacking wrt *SS* phase- shown on traveltime kernels with windows selected on the stack, however their boundary sensitivity remains high.

✧ Stack wrt the phase needed to be enhanced, check whether other phases show less important sensitivity.

✧ Add noise to synthetics to establish the essentiality of our methodology & promote constructive interference of desired phase(s).

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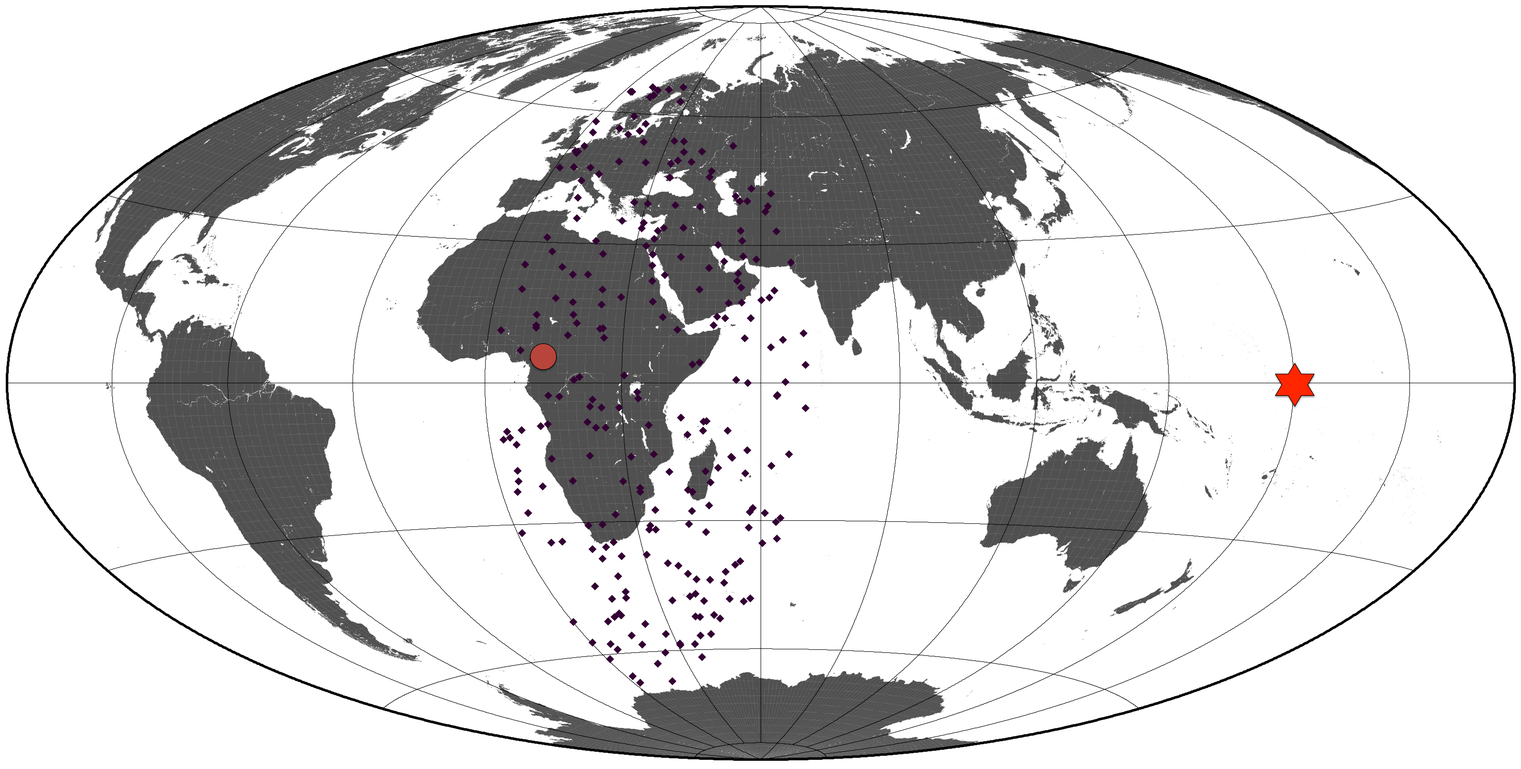

FICTITIOUS ARRAY

Red star represents an earthquake event used for the numerical modelling.

Purple diamonds show the stations recording the event. Epicentral distances range between 110-160 degrees.

Red circle at ~150 degrees shows the reference station whose recording has been used to align and sum the rest of the seismograms.

Ideally, with our study, we would like to optimise the usage of data from not necessarily dense arrays, but rather develop kernel stacks which can enhance desired signals from many stations located far apart.