As the developing of earth science, geoscientists are paying more attention to high resolution tomographic images of 3D geological structures, especially at regional scale. However, because of the high computation cost for 3D seismic wave modeling in large-scale inhomogeneous media and insufficient data coverage, it remains a challenge. Thanks to the deployment of permanent and temporary broad-band seismic arrays, coverage and data quality have been dramatically improved recently. Owing to advances in high performance parallel computing and numerical simulation techniques, seismologists begin to move from asymptotic ray-based tomography methods to more computationally demanding broad-band waveform-based inversion approaches for 3D imaging of the subsurface.

Among various waveform-based inversion approaches, the adjoint tomography has gained popularity and has been applied successfully in various geodynamic content. Furtherly, compared to most adjoint tomography approaches mainly based on inversion of phase arrival time, the full waveform inversion (FWI) method has the potential to image structures with a theoretical resolution comparable to the shortest wavelength of the inverted wavefield, for which it receives much attention by seismologists. However, FWI is an ill-posed and highly non-linear inverse problem which is sensitive to many aspects: the data noise, the starting model, trapping in the secondary minimum of the misfit function owing to cycle skipping problems, etc.

In this study, we try to resolve these issues of FWI in teleseismic application by an example of high resolution imaging of lithospheric structure beneath the Pyrenean range. In order to obtain finely resolved tomographic images for quantifying the highly controversial formation history of the Pyrenees, we perform FWI on short period teleseismic P wave records collected by stations in this region. We use a hybrid method that couples a global wave propagation method in a 1D Earth model to a 3D spectral-element method in a regional domain with a boundary coupling approach on boundaries of the regional domain. It restricts the costly 3D computations inside the regional domain, which dramatically decreases the computational cost, allows us to compute teleseismic wavefields down to 1s period. By using the hybrid method, the sensitivity kernels of the waveform misfit function with respect to elastic and density perturbations in the regional domain are computed with the adjoint method. These waveform sensitivity kernels are used in an iterative L-BFGS algorithm to invert broad-band waveform data recorded by dense transects deployed during the temporary passive experiments across the Pyrenees. We obtain high resolution lithospheric sections of compressional and shear velocities across the Pyrenean orogenic belt. The tomographic models provide clear evidence for subduction of the thinned Iberian crust beneath the European plate (Figure 1). We also compare the tomographic models obtained by FWI and phase adjoint tomography. Since FWI includes as much information as possible in the inversion (such as amplitude and coda information), it leads to better resolution than phase adjoint tomography for the same dataset, especially in the cases of sparse data coverage and short duration temporary deployments. Based on successful application of FWI, we believe that FWI approach could fill the resolution gap between high resolution images of the crust obtained from receiver function and local earthquake tomography and lower resolution teleseismic travel time tomography images of the upper-mantle.

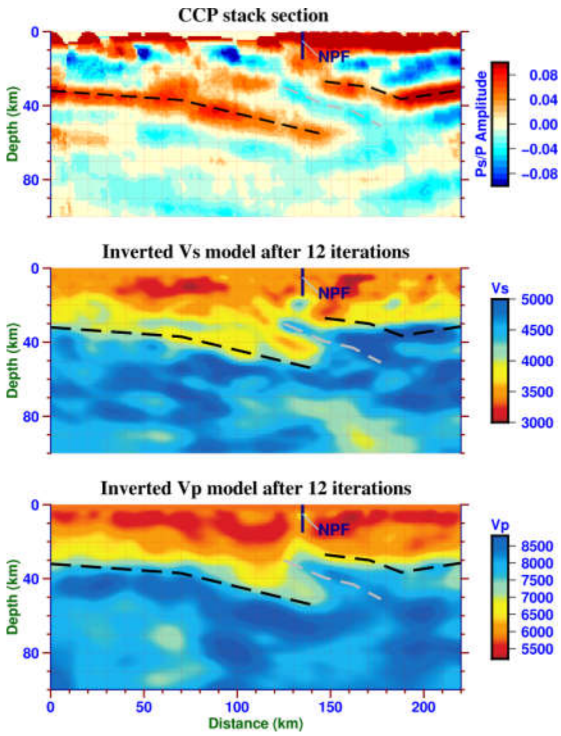

Figure 1 Top panel: CCP stack of receiver functions for the central PYROPE transect (Chevrot et al., 2015). Middle and bottom panel: V_s and V_p models obtained by FWI on the dataset of the central PYROPE transect. The Iberian and European Moho are represented as black dashed lines and the top of the subducting Iberian crust as a grey dashed line, obtained from the CCP stack section.