The aim of this thesis was to determine a new tomographic S-wave velocity model of the Hellenic subduction zone using the high quality data collected during the EGELADOS project which afforded the deployment of a dense and homogeneous seismographic network all over the southern Aegean. This excellent coverage and the use of a large frequency band enable resolving anomalies with a dimension down to approximately 30 km in the upper parts of the crust. This tomographic study was thus intended, within the framework of the Collaborative Research Centre 526 “Rheology of the Earth - From the Upper Crust to the Subduction Zone”, to reach an unprecedented spatial resolution in this zone of strong deformations, allowing to highlight in more details part of its complicated geological setting. In this vein, the full waveform inversion following the Born scattering theory was the appropriate approach permitting to take advantage of the complete seismic waveforms and link any change in the displacement field to changes in the elastic properties of the earth. The forward problem was also solved within the context of the finite frequency approximation thanks to the GEMINI program package which was used to construct synthetic seismograms and compute sensitivity kernels in the frequency domain.

Before the 3D inversion, special care was taken to guarantee the best possible accuracy of earthquakes parameters and initial reference models. In fact, locations and source mechanisms of most earthquakes that occurred during the period of deployment of the EGELADOS network were either not available or suffered from inaccuracy. As a first step, picking of P and S waves onsets permitted to obtain a good earthquake localization while a specific method based on waveform fitting of observed seismograms and synthetics calculated for a range of fault angles and hypocenter’s depths, provided the most accurate focal solutions and improved the localization when needed. On the other hand, because of the strong deformation in the Hellenic subduction zone, it was not possible to use a 1D average model that can approximate at best this complicated lithospheric structure and thus, satisfy the linearization inherent to the use of sensitivity kernels in the inversion. To solve this problem, a grid search was done by varying the average shear wave velocity in the crust and Moho depth. For each source-receiver path, the 1D model presenting the smallest misfit between synthetics and observed data was taken as the path-specific reference model. In this case, the non-linearity of the inverse problem was reduced considerably and linearized expressions for the difference between observed and synthetic waveforms in terms of sensitivity kernels became justified. A 1D inversion to refine these results was then
conducted taking these grid search models as initial references. The synthetic waveforms resulting from these models exhibit a very good phase and amplitude fit with the observed ones and a clear consistency with the results of previous studies.

Before performing the 3D waveform inversion in the frequency domain, the sensitivity kernels for each path were computed and a special formulation was elaborated to adapt the path specific approach to the classical linear inverse theory. This was done by adding a correction term which accounts for the difference between the path-specific and the global reference model. Adding to that, a regularization was applied by smoothing and damping constraints and the equations for each path were weighted according to the magnitude of each earthquake and the clustering noticed in some regions. Finally, this system of linear equations relating the data to the model parameters by the sensitivity kernels including weighting and regularization constraints was solved in a least squares sense using the ASKI program package. The first application was performed to assess the resolution with a checkerboard of anomalies of different sizes. The results of these resolution tests restrict the range of acceptable resolution to 50 km average depth in the whole southern Aegean but can go even deeper for some isolated areas.

The 3D tomographic model obtained from the full waveform inversion resolves in detail the crustal structure of the southern Aegean especially in its eastern part. One of the major features imaged by the 3D model is the eastern part of the volcanic arc where most of the actual volcanic activity concentrates. In this region, very low velocities indicate probably the presence of upwelling of magmatic material that causes the volcanic activity. The crustal thickness in the southern Aegean show strong variations in the whole region with a shallower Moho in the volcanic arc and the Cretan Sea (from 18 km to 25 km) and a thicker one beneath the entire forearc especially in its south-eastern part (from 45 to 50 km). The 3D model images also a low velocity anomaly throughout the upper 20 km beneath the forearc and a thinning of the crust in the Gulf of Corinth.