Controlled-source seismology utilizing OBS (Ocean Bottom Seismometers) is the method of a choice to study the deep lithospheric structures in the marine environment. It gives us a chance to understand the geodynamical processes occurring in the areas of oceanic ridges or subduction zones and governing e.g. nucleation of large earthquakes. However, the detailed imaging of the deep geological settings requires an active technological development breaking the long-standing limitations of the crustal-scale seismic data acquisition and processing techniques.

The current direction of the development of this kind of experiments is the transition toward a new generation of dense 3D surveys employing both OBS and long-offset wide-azimuth MCS (Multi-Channel Streamer) data. Although the ability to gather large pools of instruments and availability of advanced acquisition systems is increasing, the logistic aspects of the seismic data acquisition at this scale is still challenging. On the other hand, the evolution of the experimental settings, must go in pair with the intensive technical development of the processing methodologies such as Full Waveform Inversion (FWI), allowing to build the high-resolution crustal-scale velocity models.

In principles, the FWI is an iterative procedure dedicated for seismic imaging, which finds the subsurface model providing the best fitting between the field-recorded seismic data and the synthetic seismograms simulated in this model. Since the pioneering work of Albert Tarantola in 1984, FWI has been undergoing an active development in both academia and oil and gas industry. The method is especially appealing since it allows to develop the subsurface models with a much better resolution than can be achieved using First Arrival Tomography (FAT; a half-wavelength versus the width of the first Fresnel zone) and has the potential to be utilized for multiparameter reconstructions e.g. density or attenuation.

Despite the methodological development of the waveform inversion technologies during last decade, only a few successful attempts of FWI application to the crustal-scale OBS data were conducted. Therefore the scientific aim of this project is twofold and consist of both experimental and methodological objectives. Our fundamental goal is to use the synthetic and real OBS crustal-scale seismic data combined with novel processing techniques – namely FWI – to anticipate the high-resolution structure and geodynamical evolution of the eastern Nankai Trough. This one of the most complex and fascinating subduction zones on Earth is the subject of wide range of investigations. In particular, due to the proximity of the collision zone between the Izu-Bonin Arc and central Japan, the Tokai segment (eastern Nankai Trough) is characterized by high geodynamical complexity and the significant deformation of the surrounding structures including formation and subduction of the volcanic ridges, which during the subduction process govern the nucleation and propagation of the large earthquakes.

Hence, from the methodological point of view, through this project we would like to rise and verify the hypothesis that the FWI of the 2D crustal-scale seismic data acquired in the geologically complex area (e.g. subduction zones) gives superior results in terms of model reconstruction and data fitting when conducted within the 3D rather than 2D models. Indeed, when aiming on the 2D seismic data acquisition in such sophisticated lithospheric environment one needs to be aware of propagation of the wavefield along all planes – for example along faults which are not aligned with the axis of the 2D shooting profile. Hence the seismogram recorded at the receiver position represents the information gathered along the “out-off-the-plane” wavepath which is in fact 3D. The significance of this effect seems to be especially important in case of crustal-scale seismic profiles, where the source-receiver offsets are very long and therefore the wavefront is more prone to 3D effect. Therefore the approach considering only 2D velocity model reconstruction bears the inherent inaccuracy caused by the 3D wavefield spreading.

We will firstly verify our hypothesis against the synthetic OBS dataset generated within the realistic model of the subduction zone. We will develop the high-resolution 3D visco-elastic crustal-scale benchmark model suitable for testing various tomographic approaches and available for geophysical community around the world. Consequently we will conduct synthetic study with two variants of FWI – 2D and 3D – to examine how accounting for the 3D wavefield scattering improves the final results. The final objective, will be to transfer the gathered conclusion from the numerical study into the analogous real OBS dataset application. We will use the data recorded along 210-km long profile in the area of eastern Nankai Trough. Based on this dataset we will reconstruct the velocity model on the resolution allowing for high-confidence structural interpretation of the region.