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Full Seismic Waveform Inversion for the Japanese Islands

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We present a seismic tomography model for the Japanese archipelago obtained using full waveform inversion and adjoint methods. A credible seismic velocity model is essential for the Japan region as a means to further our understanding of earthquake source mechanics by allowing for more accurate seismic source inversion, to benefit seismic hazard assessment as well as early warning systems, and to comprehend the complexity of the tectonic setting.

The study area covers the Japanese islands, Taiwan, Korean peninsula, easternmost parts of China and Russia, Sakhalin and the majority of the Kuril Islands chain. The domain extends down into the mantle transition zone. We choose 58 earthquakes of magnitudes Mw5.0 – 6.9 distributed across the model domain as uniformly as possible. The data are obtained from several seismic networks in the area, namely F-net in Japan, BATS in Taiwan, South Korean National Earthquake Network and several stations from each China National Seismic Network, New China Digital Seismograph Network, Global Seismograph Network and Korean Seismic Network made available by IRIS Data Management Center.

To facilitate full waveform inversion the forward problem is solved numerically using the spectral element method (SEM), which comes with the geometric flexibility of the finite-elements method and the accuracy of the spectral methods. Owing to the SEM and the advance in High Performance Computing we are able to perform numerical simulations of seismic waves in realistic 3D heterogeneous visco-elastic structures. Differences between the calculated and the real waveforms are quantified using the time-frequency misfits (Fichtner et al., 2008), which allow us to explore the temporal evolution of the frequency content of the data with no need to identify specific seismic phases. We use adjoint methods as an effective means to obtain sensitivity kernels and ultimately gradients, required for iterative gradient-based minimisation techniques.

The obtained model explains the data better than the starting model for periods as low as 20 s. This is also true for the data that had not been originally used in the inversion. The final results of this study will contribute to the 'Comprehensive Earth Model' being developed by the Computational Seismology group at ETH with the aim to represent the snapshot of the current knowledge of the Earth's internal visco-elastic structure.