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Full Seismic Waveform Tomography of the Japan region using Adjoint Methods

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We present a full-waveform tomographic model of the Japan region based on spectral-element wave propagation, adjoint techniques and seismic data from dense station networks. This model is intended to further our understanding of both the complex regional tectonics and the finite rupture processes of large earthquakes.

The shallow Earth structure of the Japan region has been the subject of considerable tomographic investigation. The islands of Japan exist in an area of significant plate complexity: subduction related to the Pacific and Philippine Sea plates is responsible for the majority of seismicity and volcanism of Japan, whilst smaller micro-plates in the region, including the Okhotsk, and Okinawa and Amur, part of the larger North America and Eurasia plates respectively, contribute significant local intricacy. In response to the need to monitor and understand the motion of these plates and their associated faults, numerous seismograph networks have been established, including the 768 station high-sensitivity Hi-net network, 84 station broadband F-net and the strong-motion seismograph networks K-net and KiK-net in Japan. We also include the 55 station BATS network of Taiwan.

We use this exceptional coverage to construct a high-resolution model of the Japan region from the full-waveform inversion of over 15,000 individual component seismograms from 53 events that occurred between 1997 and 2012. We model these data using spectral-element simulations of seismic wave propagation at a regional scale over an area from 120°-150°E and 20°-50°N to a depth of around 500 km. We quantify differences between observed and synthetic waveforms using time-frequency misfits allowing us to separate both phase and amplitude measurements whilst exploiting the complete waveform at periods of 15-60 seconds. Fréchet kernels for these misfits are calculated via the adjoint method and subsequently used in an iterative non-linear conjugate-gradient optimization. Finally, we employ custom smoothing algorithms to remove the singularities of the Fréchet kernels and artifacts introduced by the heterogeneous coverage in oceanic regions of the model.