Investigating trade-offs in anelastic waveform tomography for global-scale models

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If the Earth would be purely elastic, the amplitude and phase of seismic waves would be controlled by geometric spreading, transmission, and reflection effects only. Once excited by an earthquake, the seismic waves would propagate indefinitely with the total energy of particle motion kept constant for all times. Luckily, the Earth is not perfectly elastic; seismic waves attenuate due to several processes, which are generalized as "internal friction". Such media is called anelastic, and the parameter to quantify this effect is the "quality factor", Q, which is the inverse of attenuation (Q^{-1}). The attenuation of seismic signals plays a crucial role in constraining water content, partial melting, and temperature variations in Earth's crust and mantle. Thus, improving the resolution of seismic anelastic models is essential for better understanding the Earth's subsurface structure and its dynamics.

Unfortunately, tomographic attenuation models are typically less resolved than seismic wave velocities models mainly due to amplitude measurements' complex nature, which are sensitive to scattering/defocusing, anelasticity, source radiation pattern, and source magnitude. Moreover, attenuation changes not only amplitudes but also seismic wave velocities as it causes physical dispersion. Taking the full 3D complexity of seismic wave propagation into account helps minimizing the bias from ignoring scattering/defocusing effects in classical anelastic models. Many synthetic tests have so far been performed to validate anelastic waveform tomography. However, the trade-off between elastic and anelastic parameters, which may be highlighted more at the global scale because of sparse data coverage, remains to be investigated and understood in a full 3D setup. Uncertainty in anelastic models also affects the resolution and accuracy of elastic models, as all elastic models are constructed based on a chosen attenuation model at a specific center frequency. Thus, we aim to find suitable inversion strategies to tackle these challenges.

In a first step, we test the resolution and trade-off between elastic and anelastic parameters by conducting a synthetic full-waveform benchmark, targeting an existing global 3D attenuation model and initial 1D Q-model. Although we investigate whole mantle inversions down to the core mantle boundary together with the crust, our primary focus will be in the upper mantle where the low-Q layer in 1D Q-models, located at around 200 km depth, causes the main challenge, specifically in surface-wave propagation. Our measurement period range lies within 50 to 250 s for which the Cowling approximation to self-gravitation in the numerical wave propagation solver SPECFEM3D_GLOBE is still accurate. The main goal is to assimilate both phase and amplitude data in our seismic inversions. The anelastic/elastic iterations are performed on PRACE's Marconi100 system, taking advantage of the GPU hardware accelerators. We will present our benchmark results which allow us to refine strategies for large-scale anelastic inversions.