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Towards Global Adjoint Tomography

E. Bozdag (1), H. Zhu (1), D. Peter (1), J. Tromp (1,2)

(1) Department of Geosciences, Princeton University, Princeton, NJ, USA (bozdag@princeton.edu), (2) Program in Applied & Computational Mathematics, Princeton University, Princeton, NJ, USA

Adjoint tomography based on 3D wave simulations provides new opportunities to improve tomographic images for the following reasons: 1) the full non-linearity of wave propagation may be taken into account in the forward problem, 2) 3D background models may be used to compute Fréchet kernels and, 3) seismic models may be updated in an iterative scheme. Our aim is to use this technique based on a spectral element method (Komatitsch & Tromp 2002) to obtain a global Earth model, which is becoming feasible with current computational facilities. To this end, we select 255 global CMT events distributed worldwide having moment magnitudes between 5.8 and 7. As a reference earth model, we use 3D transversely isotropic mantle model S362ANI (Kustowski et al. 2008) with 3D crustal model Crust2.0 (Bassin et al. 2000). In numerical simulations, Moho variations in Crust2.0 are honored if crustal thickness is less than 15 km or greater than 35 km to have a better sampling of the crustal model, particularly very thin oceanic crust. Using the advantages of numerical simulations, our strategy is to invert crustal and mantle structure together to avoid any bias introduced into upper-mantle images due to "crustal corrections", which are commonly used in classical tomography. Prior to the structure inversion, we reinvert global CMT solutions by computing Green functions in the 3D reference model to take into account effects of crustal variations on source parameters. Changes in source parameters are modest, but consistent with reported global CMT errors. In general, inversion results of selected earthquakes indicate a decrease in depth, particularly for ridge events, which can be up to 12 km, and a change in scalar moment of less than 30%. Event locations mostly change by less than 5 km. We use the updated CMT solutions to run forward simulations for adjoint tomography and plan to reinvert source parameters whenever we see a significant improvement in our tomographic model. 3D simulations dramatically increase the usable amount of data, which helps close the gap in data coverage due to the uneven global distribution of earthquakes and stations. Our measurements are based on traveltime differences between observed and synthetic seismograms measured as a function of frequency. We compute sensitivity kernels for the selected events combining long period surface waves ($T > 60$ s), where it is easier to handle non-linearities due to the crust, with shorter period body waves ($T > 27$ s), which are more sensitive to deeper parts of the mantle. We ultimately aim to obtain a transversely isotropic global model using an iterative preconditioned conjugate-gradient scheme.