Global Full-Waveform Inversion: Towards Exascale Imaging of Earth's Interior

Ebru Bozdağ[1], Matthieu Lefebvre[2], Dimitri Komatitsch[3], Wenjie Lei[2], Judith Hill[4], Ridvan Orsvuran[5], Daniel Peter[6], Norbert Podhorszki[4], David Pugmire[4], Youyi Ruan[2], James Smith[2], Jeroen Tromp[2]

Colorado School of Mines[1], Princeton University[2], University of Aix-Marseille[3], Oak Ridge National Laboratory[4], University of Côte d'Azur[5], King Abdullah University Science & Technology[6]

Global adjoint tomography is currently one of the most challenging projects in seismology in terms of computational requirements and big data that can potentially be assimilated in inversions. GLAD-M15 (Bozdağ et al. 2016) is the first global adjoint tomography model (Figs. 1 & 2) where no approximations — other than the chosen numerical method (Komatitsch & Tromp (2002) — were used in simulations of synthetic seismograms and how seismic waves sense the Earth structure. It is the result of 15 conjugate-gradient iterations where the crust and mantle were jointly inverted avoiding "crustal corrections". It has transverse isotropy confined to the upper mantle. Seismic data from 253 selected earthquakes were used during its construction. Simulations are performed on Oak Ridge National Laboratory's (ORNL) Cray XK7 Titan system. We now demonstrate different parametrizations to better capture the physics of the mantle and earthquakes to construct the next-generation models. Meanwhile we gradually increase the database and the resolution down to 9 s on ORNL's next-generation super computer "Summit". Our ultimate goals are 1) to use data from all earthquakes from the CMT catalogue (~6000 events since 1999) and all permanent & temporary networks available from IRIS, and 2) to go down 1 s in global simulations to invert for the entire planet including the core. To this end the entire workflow is being optimised and automatised to fully take the advantage of the HPC systems in the exascale era, reduce human error and promote reproducibility in science. All the tools for pre- & post-processing stages and visualization as well as the numerical solver are publicly available through GitHub repositories and Computational Infrastructure for Geodynamics (CIG).

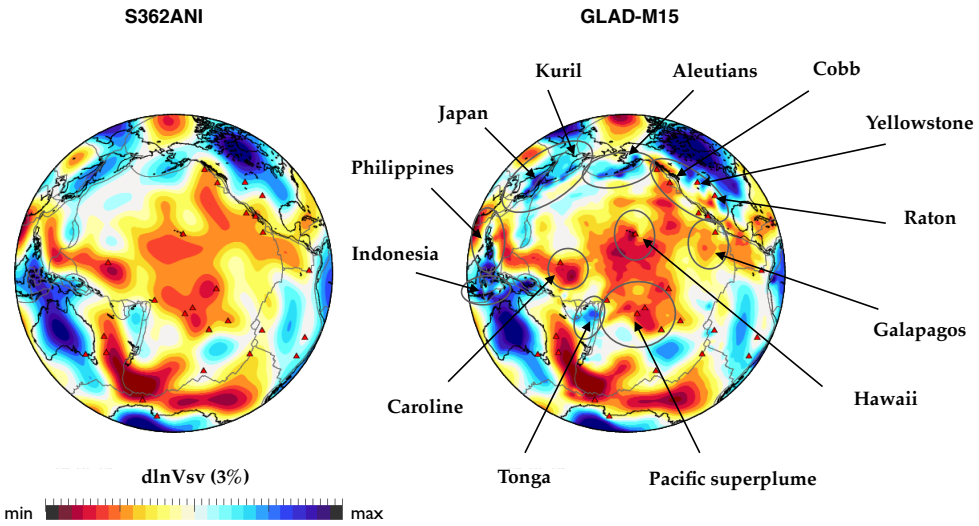

Figure 1: *Map views of vertically polarized shear-wavespeed perturbations in starting mantle model S362ANI (Kustowski et al. 2008) and GLAD-M15 (Bozdag et al. 2016) at 250 km depth. Notable slabs (blue) and plumes/ hotspots (red) enhanced in GLAD-M15 are marked. Each model is shown with respect to its own mean.*

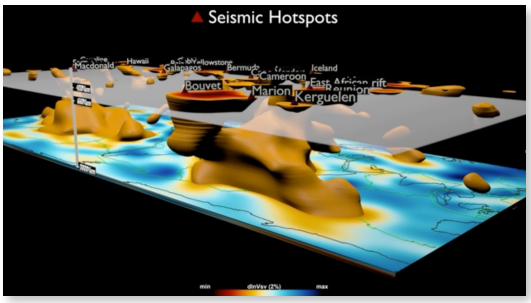

Figure 2: *A snapshot of the 3D contour movie of negative shear-wavespeed perturbations of GLAD-M15 showing major plumes/hotspots in mantle. The bottom layer is core-mantle boundary at ~2900 km. Movie by David Pugmire from ORNL (https://www.olcf.ornl.gov/2017/03/28/a-seismic-mapping-milestone/).*