A New Generation Earth Mantle Model from Global Adjoint Tomography

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Plumes rise from the deep mantle due to thermal or/and chemical buoyancy, forming hotspots at the surface, and oceanic plates subduct underneath continents, piling up at discontinuities or sinking down to the core-mantle boundary. Despite these basic convection mechanisms, many questions remain about the origin of mantle plumes, slab subduction, their interaction with mantle transition zone, and their relationship with the large low shear velocity provinces (LLSVPs) at the base of the mantle. High-resolution images of the morphology of mantle plumes and slabs, especially in the mid-mantle, are key to answering these questions.

Imaging plumes and slabs in the mid and lower mantle is known to be very challenging due to a lack of dense seismic data coverage and resolvability limits of conventional body-wave traveltime tomography. Rather than identifying known phases, using all possible waveforms provides a better sampling of the mid-mantle depth range from 400 km to 1000 km. We applied very conservative criteria for time window selection and measurement screening to 1,480 carefully selected earthquakes from a global database (Mw~5.0--7.0, January 1995 to December 2016), which is nearly 6 times larger than used in a first-generation study (GLAD_M15, Bozdag et al. 2016). We reinverted Centroid Moment Tensor (CMT) solutions of the 1,480 events using model GLAD_M15 and recalculated synthetic seismograms. Using the synthetics as reference seismograms, we selected time windows that show good agreement with data and make measurements within these windows. From the measurements, we have assimilated more than 15 million windows in three-period bands (17-40~s, 40-100~s, and 90-250~s).

Harnessing the power of the supercomputer "Titan" at Oak Ridge National Laboratory, we employed a spectral-element method to accurately simulate synthetic seismograms in complex 3D Earth models and an adjoint method to obtain Fréchet derivatives for model updates. We constructed our new generation transversely isotropic earth model based on 10 iterations. We imaged fine-scale features of mantle plumes and slabs, even in areas with relatively sparse data coverage. Using maps of Vp, Vs, Vsv/Vsh, and Vp/Vs ratios from the new model, we found evidence of partial melting in LLSVPs, interactions of plumes with the volatile-enriched mantle transition zone, and the mantle intrusion mechanism for the Yellowstone hotspot. We will present a summary of the new inversion results based on our current model, GLAD_M25.