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Towards Tidal Tomography: Using Earth's Body-Tide Signal to Constrain Deep-Mantle Density Structure

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Luni-solar forcings drive long wavelength deformation at timescales ranging from 8 hours to 18.6 years. We propose that globally distributed GPS estimates of this deformation within the semi-diurnal band provide a new and independent constraint on long-wavelength deep mantle structure. A particular target of "tidal tomography" is the buoyancy structure of LLSVPs, which constitute a large volumetric fraction of the mantle. Constraining this structure is the key to understanding the longevity of the LLSVPs, and indeed the evolution of the entire mantle and Earth system. To this end, we begin by reporting on the development of a new normal-mode theory, based on relatively recent advances in free oscillation seismology, which is capable of predicting semi-diurnal body tides on a laterally heterogeneous, rotating and anelastic Earth. We next present the results of a suite of benchmark tests involving comparisons with predictions based on both classical tidal Love number theory for 1-D Earth models and finite-volume simulations that incorporate 3-D elastic and density structure. We find that body tide deformation is most sensitive to long wavelength, deep mantle structure, and, in particularly, to shear wave velocity and density structure. When combined with results from seismological datasets, this sensitivity provides a powerful tool to investigate the buoyancy structure of the LLSVPs. For example, adopting a variety of seismic tomography models a priori, we perform an extensive parameter search to determine misfits between model predictions based on the new theory and GPS-derived estimates of the semi-diurnal body tide displacements. Preliminary results, focusing only on density structure, have indicated that the observations are best fit when the LLSVPs have a bulk density greater than average mantle, in broad agreement with previous inferences based upon seismic normal mode inversions. In follow-up work, we have mapped out trade-offs related to the adopted seismic tomography model, deep mantle buoyancy structure, and topography of both the core-mantle boundary (CMB) and 670 km seismic discontinuity. The goal of this analysis is to address the following question: given all available models of shear-wave velocity structure and topography at internal discontinuities, what are the bounds on the buoyancy structure of the LLSVPs lie that satisfy space-geodetic measurements of body tide deformation—a dataset currently unexploited in investigations of deep mantle structure.