Velocity and density structure of the deep mantle from Earth's free oscillations

At nearly 2900 km depth, the core-mantle boundary (CMB) separates the liquid iron core and the solid silicate mantle, marking a change in temperature and composition even larger than at the Earth's surface. At this interface, dynamic processes occurring in the mantle and core interact, producing a range of structures at scales from tens to thousands of kilometres. Seismic observations of these structures provide an insight into the dynamics of the deep Earth and the evolution of our planet.

Shear-wave tomography models consistently image lower-than-average shear-wave (Vs) velocities in two regions underneath the Pacific and Africa. These large-low-shear-velocity-provinces (LLSVPs) extend thousands of kilometres laterally and rise up to 1000 km above the CMB. Despite improved seismic imaging, we still fall short of conclusive interpretations regarding their origin and role in mantle dynamics; are they dominantly thermal structures or are chemical variations required to explain our seismological observations? Information on their density structure and shear to compressional-wave velocity (Vp) ratio is vital for addressing these questions and assessing their influence on mantle dynamics.

Normal modes or Earth's free oscillations provide an invaluable tool for probing the Earth's deep interior since they are global in character and are affected by density structure in addition to velocity variations. In particular, CMB Stoneley modes, confined to the solid-liquid interface of the CMB, are primarilysensitive to structures in the lowermost mantle. Observations of these modes increase the depth resolution and provide unique constraints on the long wavelength structures in the deep mantle.

Several large magnitude earthquakes have occurred in the last decade, significantly increasing the amount of available data for normal mode observations. We make use of a recent normal mode splitting function data set of 143 modes including 33 modes sensitive to compressional wave velocity and 9 CMB Stoneley modes.
We combine our normal mode data with independent constraints from body waves and surface waves and invert jointly for lateral Vs and Vp variations in the Earth's mantle. The resulting model SP12RTS is analysed in terms of the ratios and correlations of the seismic velocities. Subsequently, we compare our model to thermal and thermochemical models of mantle convection. Our tomographic-geodynamic model comparison suggests that several seismic observations can be explained by the presence of the lower mantle post-perovskite phase, but it it allows no discrimination between isochemical and thermochemical models of mantle convection. In addition, we study the density structure of the LLSVPs by forward modeling of possible density scenarios for the lowermost mantle. We discuss our results in the light of thermal versus thermochemical variations in the Earth's mantle.