Exploring origin and composition of the lowermost mantle structures with machine learning methods and seismology

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Project Description

The lower mantle of the Earth is home to a variety of anomalous structures with different scales. This includes two continent-sized structures, the large low shear velocity provinces (LLSVPs), which are consistently observed across the existing 3-D tomographic models. Conversely, small- to meso-scale structures such as ultralow-velocity zones (ULVZs) or mega-ULVZs are often below the current resolution of those tomographic models, but can be studied using seismic wavefield simulations of various seismic phases that have been scattered or multipathed by such heterogeneities in the core-mantle boundary (CMB) region (**Figure 1**). Although the origin and nature of these structures are still largely unknown, recent studies suggest that they are capable of hosting primordial geochemical reservoirs and are therefore intimately tied to important geological processes that govern Earth's long-term evolution. These processes likely entail interactions between contrasting materials from the mantle and core, possibly aided by deep-seated mantle plumes.

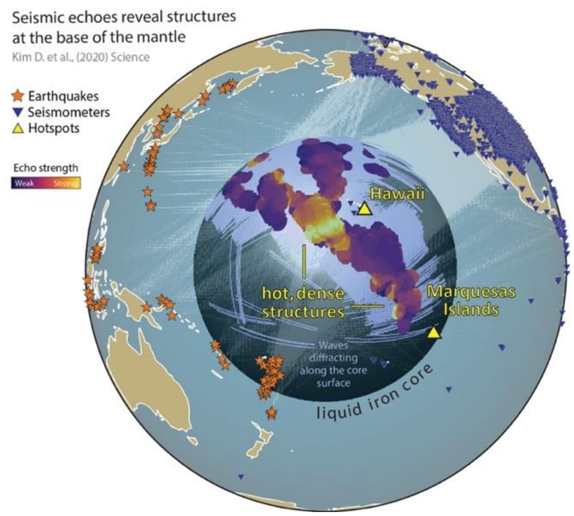

Figure 1*: By sequencing seismograms, we find an previously unrecognized ultralow-velocity zone (ULVZ) beneath Marquesas Islands, and pervasive scattering near the core-mantle boundary, strongest from a plume root under Hawaii. After Kim et al., (2020)*

The aim of this project is to explore terrestrial waveform data and identify uncommon seismic phases that will allow us to understand the origin and dynamic interaction between lowermost mantle structures. Previous approaches using scattering of seismic waves have revealed subsurface structures on the CMB region, but in a piecemeal way focused on specific target areas. Here, (1) we intend to systematically analyze global waveform data with diverse data mining techniques to identify exotic seismic phases (https://www.science.org/doi/10.1126/science.abc3134). (2) By implementing the 3-D finite frequency sensitivity kernels computed using adjoint methods, we can invert both amplitudes and travel times observed from those exotic phases for seismic velocity perturbation required in the CMB region. This work enables us to extract crucial constraints on both structural and compositional characteristics of anomalous bodies within the Earth's CMB region, including not only ULVZs and LLSVPs, but also other potential lowermost mantle anomalies such as plume conduits and slab remnants.
The successful candidate will join, and be supported by, a vibrant and dynamic research group with world-class expertise modelling geophysical flows. The candidate will have the

opportunity to develop their career and profile by presenting at international conferences and publishing in high impact journals. Candidates for PhD positions should have a good mathematical background and a degree in an appropriate field such as earth science, physics, mathematics, computer science or engineering.