The University of Oxford Department of Earth Sciences

EARTHSCIENCES

Imaging the multi-scale topography of the Earth's core

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Key Words	**Geophysics, Seismology, Deep earth structure, core-mantle boundary**

Overview

Similar as on the Earth's surface, intriguing landscapes are present deep inside our planet that can be imaged with seismological data. Particularly, it is crucial to image the landscape of the core-mantle boundary (CMB). Improved observational constraints on the topography of this boundary provide critical insights into dynamic processes in the mantle and core (Koelemeijer, 2021), leading ultimately to better constraints on the history of our planet.

The topography on the Earth's core-mantle boundary is inherently linked to the density structure of the deep mantle through isostasy and dynamic flow effects. Accurate observations of CMB topography therefore help to constrain mantle viscosity and density (e.g. Deschamps et al., GJI, 2018). These two quantities are vital for determining the driving forces of mantle flow. In addition, lateral variations in CMB topography break the symmetry of the dynamic regime in the outer core, influencing core flow and the geodynamo, topics of active research in the deep Earth community.

Accurately constraining the topography of the Earth's core remains an outstanding issue in deep Earth research. The recent review by Koelemeijer (2021) identified a discrepancy between models based on observations of high-frequency travelling waves (body waves) and long-period standing waves (normal modes), which provide information on different scale lengths. This review also indicated ways in which progress may be made, specifying methods and data that are most suitable to be used. These recommendations form the basis of this PhD project, partly funded by the Royal Society, with the main objective to develop a model of CMB topography that is consistent with a wide range of seismological data.

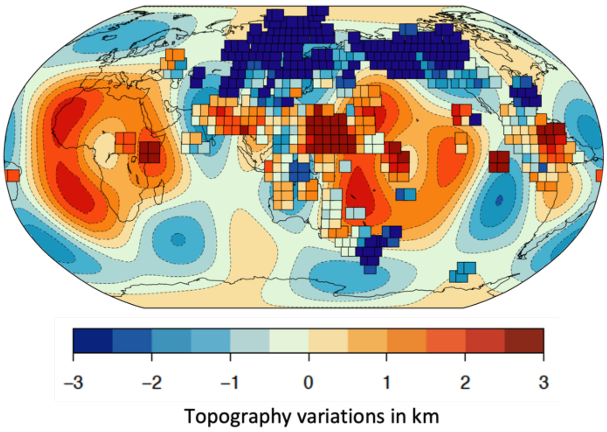

Figure showing possible topography variations on the Earth's core-mantle boundary (CMB), derived from normal modes (smooth background field) and body waves (colored blocks superposed on the background).

Methodology

The student will first assemble a data set of body wave phases that interact with the core-mantle boundary in different ways (i.e. reflecting, refracting). The raw waveform data will be downloaded from the IRIS data management centre (freely accessible online). Using open-source python tools within Obspy (Krischer et al., 2015), the student will make multi-frequency traveltime measurements of these travelling waves, which will constrain Earth structure on a range of wavelengths.

Subsequently, the student will use the SOLA method (Zaroli, 2016; Zaroli et al., 2017) to invert these data for feasible CMB topography models. SOLA allows us to obtain models with unbiased amplitudes, rather than damped models of real Earth structure and to focus on the region of interest rather than having to invert for the entire mantle. The suite of models, with their uncertainties, will be tested against independent normal mode data measured by the primary supervisor and others (freely available with the relevant publications). These data provide strong constraints on long wavelengths and have global coverage. Combining these two data types within one framework is vital to resolve existing discrepancies.

Finally, the produced CMB topography models will be compared to the results of geodynamic simulations, particularly from runs with different density structures in the lowermost mantle, as part of existing collaborations of the primary supervisor. Interactions with geodynamicists will be crucial for the interpretation of the final models and also provide the student with important networking opportunities.

Timeline

Year 1: Doctoral training courses, literature review, learning of Obspy tools, data set assembly

Years 2 and 3: Data set processing, multi-frequency measurements, inversions for CMB topography using SOLA, testing of models using normal mode data

Year 4: Comparison of topography models with geodynamic predictions, thesis writing and presentation of results at international conferences.

Training & Skills

The successful candidate will join the seismology group at the University of Oxford, and benefit from interactions with existing PhD students, postdocs and faculty who work on similar topics. Through the project, they will develop a comprehensive understanding of the structure and dynamics of Earth's interior.

They will receive training in computational methods, including data analysis of big seismic data sets, as well as inverse methods and numerical modelling, all useful skills to help secure a future career as a research scientist in academia or elsewhere.

The student will also be mentored on how to prepare scientific results at (inter)national conferences, how to write manuscripts for publication in international journals and how to communicate their science to a general audience.

Besides receiving training in research and transferable skills, the student will be actively encouraged to undertake personal development courses and benefit from career support and advice on funding applications by the primary supervisor.

References & Further Reading

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Further Information

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