[S3-P01] Plausible mechanisms to convey primordial isotopic signatures of the core to ocean island basalts

John Hernlund[1], Irene Bonati*[1], Scott Hull[2], Steven Desch[3], and Wendy Panero[2]

[1]Earth Life Science Institute (ELSI) – Japan
[2]Ohio State University (OSU) – United States
[3]Arizona State University (ASU) – United States

Abstract

Isotopic fingerprints of core-mantle interaction have long been sought. Signs of core-mantle chemical interaction might have surficial manifestations in "ocean island basalt" (OIB) lavas derived from hot upwelling plumes sourced from the core-mantle boundary (CMB) region. Recently, isotope measurements of OIBs show negative mu182W, reduced D/H, and elevated 3He/4He, all of which could be expected signatures of the core. However, the difficulty of entraining dense core metal into upwelling rocky silicate mantle flows and the absence of a correlated increase in siderophile element abundances has instead motivated hypotheses that attribute such isotope variations to mantle heterogeneity alone. Here, we consider three separate mechanisms that may impart a core-like isotopic signature to upwelling plumes rooted in the CMB region: (1) Interaction with deep mantle melts in the early Earth, (2) grain-scale intrusion of liquid iron into rock that is depressed into the top of the core, and (3) upward sedimentation of solids precipitated from the core. In order to satisfy siderophile element abundances, only limited metal can be directly entrained from the core. The latter two mechanisms require that metals at the CMB form an interconnected network at the grain boundaries, even at low volume fractions, consistent with experimental constraints.

*Speaker

[S3-P02] A Simple Mathematical Model of Ultralow-Velocity Zones

John Hernlund[1], Irene Bonati*[1], and Takashi Nakagawa[2]

[1]Earth Life Science Institute (ELSI) – Japan
[2]Japan Agency for Marine-Earth Science and Technology (JAMSTEC) – Japan

Abstract

Ultra-low velocity zones (ULVZs) are seismically observed small-scale regions located at the core-mantle boundary (CMB), characterized by significant seismic velocity variations and higher densities relative to the overlying mantle. Understanding the origin, evolution, and present state of ULVZs has been hampered by numerous difficulties that are partly computational in nature. One of the primary limitations for including ULVZs in numerical models of mantle convection is the requirement of resolving length scales smaller than 0.1% of the domain thickness. Another challenge is the treatment of very large viscosity contrasts between ULVZs and the overlying lower mantle, with accuracy degrading rapidly for contrasts exceeding several orders of magnitude. Here, we extend the treatment of the dynamics of thin ULVZ layers using a lubrication theory approach originally developed by Reynolds in the 19th century, and apply it to numerical and analytical models of mantle convection in the CMB region. We show preliminary results for the motion and shape of ULVZs residing beneath an axisymmetric upwelling flow and in the context of time-dependent mantle convection. This method shows that ULVZs are preferentially concentrated in proximity of deep mantle upwellings rooted at the CMB, with very weak or absent manifestations in other areas.

*Speaker

[S3-P03] On formation of a stably stratified layer below the core-mantle boundary region: evaluating with a 1D thermal and chemical evolution model

Takashi Nakagawa*[1], Youhei Sasaki[2], and Shin-Ichi Takehiro[3]

[1]Japan Agency for Marine-Earth Science and Technology (JAMSTEC) – Japan
[2]Department of Mathematics, Kyoto University – Kitashirakawa Oiwake-chou, Sakyo-ku, Kyoto, 606-8502, JAPAN, Japan
[3]Research Institute of mathematical sciences, Kyoto University – Kitashirakawa Oiwake-chou, Sakyo-ku, Kyoto, 606-8502, JAPAN, Japan

Abstract

An existence of stable layer below the core-mantle boundary (CMB) has been suggested from various seismological data analyses (e.g. Tanaka, 2007; Helffrich and Kaneshima, 2010) and geomagnetic data analyses (e.g. Buffett et al., 2016). Possible formation mechanisms on a stable layer would be caused by both thermal and chemical effects. Recently, theoretical core evolution models with a revised value of thermal conductivity under Earth's core condition are formulated, which is proposed that a thermally stable layer of O(1000km) could emerge when the heat flow across CMB is sufficiently low compared to the isentropic heat flow (Gomi et al., 2013; Labrosse, 2015). However, a negative convective heat transfer region is identified as a stable layer in these models, which would be available for thermal convection only. In order to improve an evaluation scheme of stable layer formation with the effect of compositional convection, Takehiro and Sasaki (in review) propose to use a kinetic energy production caused by convective buoyancy driven by thermal and chemical effects based on Lister and Buffett (1995). Their illustrative calculations show that the thickness of a possible stable layer is O(100km), which is smaller than that evaluating with thermal convective flux only. In this study, since high pressure experiments suggest chemical interactions at CMB (Frost et al., 2010; Hirose et al., 2017), we investigate a chemical effect as well as a thermal effect for formation of a stable layer below CMB in new evaluation scheme proposed by Takehiro and Sasaki (in review). We incorporate compositional fluxes of oxygen and silicon across the CMB and baro-diffusion (Gubbins and Davies, 2013; Buffett and Seagle, 2010) into a theoretical core evolution model developed by Takehiro and Sasaki (in review) and diagnose thermal and compositional flux budgets for various values of CMB heat flow. Due to two orders of magnitude smaller compositional flux caused by baro-diffusion of oxygen and silicon from CMB than that caused by inner core growth, a stably stratified region below the CMB would not be found for more than around 9 TW of CMB heat flow, which is a similar result to a case with only thermal stratification (Takehiro and Sasaki, in review). As a consequence, assuming realistic core-mantle chemical interaction, it would be still required to have a lower efficiency of heat transfer across CMB for a stably stratified layer formation. More implications for core-mantle thermal-chemical coupling will be discussed in the poster presentation.

*Speaker

[S3-P04] Fine-scale Structures along the edge of the LLSVP beneath Hawaii

Voon Hui Lai*[1], Daoyuan Sun[2], Jennifer Jackson[1], Zhongwen Zhan[1], Michael Gurnis[1], and Don Helmberger[1]

[1]Division of Geological and Planetary Sciences (CALTECH) – 1200 East California Boulevard Pasadena California 91125, United States

[2]University of Science and Technology of China [Hefei] (USTC) – Hefei, Anhui, China

Abstract

Resolving fine scale structures along the edge of Large Low Shear Wave Provinces (LLSVPs) at the core-mantle boundary is paramount in understanding the compositional and geodynamical origin of these LLSVPs. While many seismic tomography models show the Pacific LLSVP, seismic waveforms at shorter period up to 5 seconds reveal a strong lateral variation in azimuth of travel time anomalies and waveform shapes across the northeastern margin, which are not predicted by the global tomographic models. The data set used in this study consists of seismic phases S, ScS and S diffracted ('Sdiff') at a distance ranges of 75 to 110 degree, originating from deep M> 6 earthquakes beneath the Fiji-Tonga region recorded by the seismic stations in US including the USarray. The most anomalous corridor occurs along the azimuth near 50 where multipathing of ScS and Sdiff are observed. These features can be modeled by including laterally varying ULVZs with tapered reduced velocity structures, favoring a primordial iron-rich residue as the interpretation of the ULVZs. The sharp changes in the differential (ScS-S) times prove difficult to model without introducing a slow plume adjacent to high velocity slab structure. Our preliminary seismic waveform-modeling results yields a complicated interaction between potential remnant slab against the edge of the Pacific LLSVP and a plume located about 12 southeast of Hawaii. This geometry is compatible with recent dynamic predictions where the Hawaii-Emperor Seamount Chain is explained.

*Speaker

[S3-P05] Strongly Anisotropic Magnesiowuestite in Earth's Lower Mantle

Jennifer Jackson*†[1], Gregory Finkelstein[2], Ayman Said[3], Ahmet Alatas[3], Bogdan Leu[3], Wolfgang Sturhahn[1], and Thomas Toellner[3]

[1]Seismological Laboratory, Division of Geological Planetary Sciences, California Institute of Technology – Pasadena, CA 91125, United States

[2]Now at: Hawai'I Institute of Geophysics and Planetology, University of Hawai'i at Manoa – Honolulu, HI 96822, United States

[3]Advanced Photon Source, Argonne National Laboratory – Argonne, IL 60439, United States

Abstract

Earth's lower mantle plays a fundamental role in the thermal and chemical evolution of the planet. The boundary between the core and mantle is a primary interface within the deep interior and has a fundamental influence on the cooling of the planet. Seismologists have shown that the mantle side of this boundary is extraordinarily complex, with km-scale fine structure embedded within larger layers of variable size and character. A combination of thermal and chemical heterogeneity, solid-solid phase transitions, anisotropy, complex rheology, and melting is likely required to explain the observed features. Ultralow-velocity zones represent one class of structures at the core-mantle boundary and are thought to correspond to either aggregates of partially molten material or solid, iron-enriched assemblages. We measured the phonon dispersion relations of (Mg,Fe)O magnesiowüstite containing 76 mol% FeO, a candidate ultralow-velocity zone phase, at high pressures using high energy-resolution inelastic x-ray scattering. We find that magnesiowüstite becomes strongly anisotropic (up to 60% for the shear waves) with increasing pressure, potentially contributing to a significant proportion of seismic anisotropy detected near the base of the mantle.

*Speaker

†Corresponding author: jackson@gps.caltech.edu

[S3-P06] New insights into the mineralogy of D” beneath the North Atlantic region

Stephanie Durand*[1], Christine Thomas[2], and Jennifer Jackson[3]

[1]Institut für Geophysik – Correnssstr. 24 48149 Muenster, Germany
[2]Universität Münster – Geophysikalisches Institut, Westfälische Wilhelms-Universität, Correnssstrasse 24, 48149 Münster, Germany
[3]Division of Geological Planetary Sciences, California Institute of Technology, Pasadena, CA, United States – United States

Abstract

In this study we provide new insights into D” mineralogy and P-T conditions beneath the North Atlantic region based on a combined analysis of P and S wave data. We use over 700 US-array station recordings of the the Mw 6.3 earthquake that ocurred in April 2010 in Spain. In order to investigate the D” layer we look for waves reflected off the top of it, and compare them to the core-mantle boundary reflections used as reference phases. The differences in travel times and amplitudes is sensitive to D” properties. Because the USarray installation generates a dense array we are able to provide an almost continuous map of the detection of PdP and SdS waves in the North Atlantic region. We use a Bayesian inversion for travel times and amplitudes to find the best fitting D” properties, Vp, Vs and thickness. We find that the D” layer is _˜292 km thick in this region and waveform modelling yields positive velocity jumps across the D” discontinuity of about 2% for both Vp and Vs. We also observe sharp lateral variations from presence to absence of the D” reflector, likely suggesting chemical variations inside D”, possibly due to the presence of the Farallon slab.

*Speaker

[S3-P07] Discriminating between causes for D" anisotropy using reflections and splitting measurements

Angelo Pisconti*[1], Christine Thomas[1], and James Wookey[2]

[1]Institut für Geophysik, Westfälische Wilhelms-Universität Münster – Corrensstr. 24 48149 Münster, Germany

[2]School of Earth Sciences, University of Bristol – Wills Memorial Building, Queen's Road, Bristol BS8 1RJ, United Kingdom

Abstract

Knowledge of deep mantle deformation is based on seismic anisotropy, the variation of seismic wave speed and polarization with direction. Measuring this directional dependency requires azimuthal seismic coverage at D" depth – the bottoming few hundred kilometers of the mantle - which is often a limit in retrieving the style of anisotropy. Shear wave splitting is the standard technique for probing mantle anisotropy and recently, reflections from the D" region have been used to infer azimuthal anisotropy. Here we combine observations and modelling of D" reflections with shear wave splitting along a given ray path direction in order to constrain a scenario of anisotropy and mineralogy of the lower mantle. From our modelling, a clear distinction between different anisotropic media is possible by using both types of observations together but only one directional path. As test region we focus on the lowermost mantle beneath the Central Atlantic Ocean by using South-Central American earthquakes recorded in Morocco. We find complex azimuthal and distance patterns for both, polarities of D" reflections and shear wave splitting parameters, which rules out a simple style of anisotropy, such a vertical transverse isotropy, for the region. Our preferred model consists of a phase transition from a randomly oriented bridgmanite to lattice preferred orientation fabric in post-perovskite, developed in a sub-horizontal plane sheared along a roughly SE-NW deformation direction.

*Speaker

[S3-P08] Exploring seismic small-scale heterogeneities in the lower mantle using PKP precursors

Xiaolong Ma[*†1] and Christine Thomas[1]

[1]Institute of Geophysics, University of Münster – Germany

Abstract

Small-scale heterogeneities in the lower mantle can scatter seismic energy that can be observed as precursor to PKP phases. Global observations indicate that these scattering heterogeneities could be on the scale of _˜10 km with _˜0.1% velocity variations in the deep mantle. Scattering could result from seismic heterogeneities (e.g., remnants of ancient subducted slabs, melt pockets or ultra-low velocity zones) and/or CMB topography. However, the primary source of these small-scale heterogeneities and relationships with seismic structures remain elusive. Here we investigate regional variations in precursor amplitude to aid the interpretation of the source of scattering. For one specific path, we collect PKP precursor waveforms from earthquakes in South America which are recorded by seismic arrays in Australia. By analysing the slowness and scatterer location, we obtain the spatial distribution of these scatterers in the lowermost mantle east of Pacific LLSVP. We further constrain the geometry and velocity variations of these strong seismic anomalies using waveform modelling. Our results show that these seismic scatterers could be interpreted as localized, patchy ULVZs, with P-wave velocity reductions of _˜8% and thickness of _˜30 km. To extend the coverage of precursor observations, we now examine a global data set of PKP precursors in individual seismograms and array data, to better constrain scatterer locations, scattering magnitudes and sources of scattering. We find strong variations of scattering amplitudes in many different paths. This helps to determine the relationship between regional variations in scattering amplitudes and timing of precursors with seismic structures in the mantle.

*Speaker

†Corresponding author: maxiaolong0313@gmail.com

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[S3-P09] Scattering and reflections in the lowermost mantle beneath the Caribbean

Vanessa Hiemer*[1] and Christine Thomas[1]

[1]Westfälische Wilhelms Universität Münster – Geophysikalisches Institut, Westfälische Wilhelms-Universität, Correnssstrasse 24, 48149 Münster, Germany, Germany

Abstract

The D" region is characterized by a variety of structures at many different scales, scatterers and ultra-low velocity zones with up to 10's of km-sizes to the large-low shear velocity provinces beneath the Atlantic and Pacific. Another prominent structure is the D" reflector that has been found in many regions.

The focus of this study is on the lowermost mantle where scattering of the PKP phase occurs and arrives as precursors to PKPdf. Here the area of interest is the region of and around the Caribbean Sea. To investigate the structure in the lowermost mantle below this region, events in Central and South America from 1991 to 2017 are used with a magnitude of 6 and greater in a depth below 100 km. The corresponding data are taken from stations in a distance of about 120 to 145○, as for example the Kyrgyz Seismic Telemetry Network (KN). The scattered and diffracted waves in the seismograms are viewed in different frequencies to look for changes in amplitude ratios of precursors to PKPdf with regard to direction and distances. These are compared with other regions where scattering is observed. We find that precursors to PKP show a dependency of amplitude with frequency. We also test directional dependencies of scattering to test whether scattering could be anisotropic.

In addition to scattering we also test the D" reflector in this region. This reflector has been observed before but we now examine it with different frequencies.

*Speaker

[S3-P10] The low geomagnetic secular variation in the Pacific and the inhomogeneous conducting lower mantle

Mathieu Dumberry*†[1] and Colin More[1]

[1]Department of Physics, University of Alberta – Canada

Abstract

Reconstructions of the temporal changes in Earth's magnetic field for the past 400 years show that the secular variation has been lower in the Pacific region, a feature further confirmed by recent satellite measurements. Core flow reconstructions suggest that one of the main reason for this is connected to a planetary scale geostrophic gyre which is offset from the rotation axis towards the Atlantic hemisphere. Because of the general downflow in the Pacific region, fewer magnetic flux anomalies are advected to the surface of the core resulting in a reduced secular variation intensity. Topographic and thermal core-mantle coupling with an inhomogeneous lower mantle, as well as hemispherical differences in inner core growth, have been proposed as possible explanations for this geographic pattern of flow and magnetic field. Here, we investigate whether electromagnetic coupling between core flows and an inhomogeneous conductivity structure at the base of the mantle can explain the lower magnetic secular variation in the Pacific as well as the offset gyre. Regions with larger conductivity tend to "screen" a greater portion of the secular variation – indeed this was one of the earliest suggestion to explain the Pacific low secular variation. However the more important effect is that a larger conductivity exerts a larger electromagnetic drag on convective structures, thus leaving little eddy action to act on the magnetic field. Using a quasi-geostrophic model of the dynamics in the core, we show how effective electromagnetic coupling is at attenuating convective columns. We also show how the planetary gyre tends to be deflected away from regions of higher conductivity in an effort to reduce the drag acting on it. Our results suggest lateral differences in the material properties of the lower mantle, and therefore offering clues and constraints on the evolution and dynamics of the mantle.

*Speaker

†Corresponding author: dumberry@ualberta.ca

[S3-P11] The Influence of Heat Flux Boundary Heterogeneity on Heat Transport in Earth's Core

Jon Mound*[1] and Chris Davies[2]

[1]University of Leeds – School of Earth Environment, University of Leeds, Leeds, LS2 9JT, United Kingdom
[2]University of Leeds – United Kingdom

Abstract

Rotating convection in planetary systems can be subjected to large lateral variations in heat flux from above; for example, due to the interaction between the metallic cores of terrestrial planets and their overlying silicate mantles. The boundary anomalies can significantly reorganise the pattern of convection and influence global diagnostics such as the Nusselt number. We have conducted a suite of numerical simulations of rotating convection in a spherical shell geometry comparing convection with homogeneous boundary conditions to that with two patterns of heat flux variation at the outer boundary: one hemispheric pattern, and one derived from seismic tomographic imaging of Earth's lower mantle. We consider Ekman numbers down to 10ˆ{-6} and flux-based Rayleigh numbers up to _˜800 times critical. The heterogeneous boundary conditions tend to increase the Nusselt number relative to the equivalent homogeneous case by altering both the flow and temperature fields, particularly near the top of the convecting region. The enhancement in Nusselt number tends to increase as the amplitude and wavelength of the boundary heterogeneity is increased and as the system becomes more supercritical. In our suite of models, the increase in Nusselt number can be as large as _˜25%. The slope of the Nusselt-Rayleigh scaling also changes when boundary heterogeneity is included, which has implications when extrapolating to planetary conditions. Additionally, regions of effective thermal stratification can develop when strongly heterogeneous heat flux conditions are applied at the outer boundary.

*Speaker

[S3-P12] Inferring lowermost mantle temperature from seismic, geodynamic and mineralogical data

Andrew Walker*[1], Chris Davies[2], Andy Nowacki[2], and Paula Koelemeijer[3]

[1]University of Leeds – School of Earth and Environment University of Leeds Leeds, United Kingdom
[2]University of Leeds – United Kingdom
[3]University of Oxford – United Kingdom

Abstract

The three dimensional temperature distribution in the lowermost mantle is diagnostic of the pattern of mantle convection and controls the extraction of heat from the outer core. Direct measurement of mantle temperature is impossible and the temperature in the lowermost mantle is poorly constrained. However, since temperature variations impact many geophysical observables, it is possible to isolate the thermal signal if mantle composition and the physical properties of mantle minerals are known.
Here we describe software that allows seismic, geodynamic, and thermal properties of the core and mantle to be calculated given an assumed temperature (T) and mineralogical (X) distribution in the mantle while making use of a self-consistent parameterisation of the thermo-elastic properties of mantle minerals. For a given T and X, this software allows us to predict the long-wavelength surface geoid, core-mantle boundary topography, inner-core radius, total surface heat-flux, and seismic velocities in the mantle.
We can use this software to relate conceptual models of one aspect of the lowermost mantle to other aspects of the deep Earth system. For example, we can build a model that explains mantle tomography and test if this is consistent with the shape of the core-mantle boundary. However, our main use for this approach takes advantage of the software's ability to run quickly (taking less than a second to evaluate the properties of a model of the lowermost mantle) and its ability to incorporate uncertainties in the mineralogical parameterisation. This makes the software suitable for use in a Monte Carlo approach to the determination of the long-wavelength temperature and composition of the lowermost mantle.

*Speaker

[S3-P13] Proxies for the presence of post-perovskite from global tomography

Paula Koelemeijer*†[1], Ana Pagu[2], Bernhard Schuberth[3], and Rhodri Davies[4]

[1]University College, Department of Earth Sciences, University of Oxford – Oxford, United Kingdom
[2]University of Oxford [Oxford] – South Parks Road, Oxford, United Kingdom
[3]Ludwig Maximilian University [Munich] (LMU) – Germany
[4]Australian National University (ANU) – Australia

Abstract

The post-perovskite (pPv) phase is commonly used as explanation for seismic features observed in Earth's lower mantle (e.g. sharp discontinuities, anisotropy, ratios and correlation of velocities). As such, it helps to constrain the core heat flow (Qcmb) and thus provides information on the energy budget of the core. Strong lateral variations in Qcmb are also thought to influence outer core flow and potentially induce magnetic field reversals. In addition, pPv displays strong anisotropy and has a low viscosity, physical properties which also affect lower mantle dynamics and convection. Thus, by mapping out lateral variations in post-perovskite, we obtain insights into dynamic processes occurring in both the mantle and core.

Traditionally, the presence of pPv has been inferred from sharp discontinuities in seismic velocities. However, this only gives a very patchy image of its lateral distribution due to our heterogeneous seismic data coverage. In addition, these interpretations are complicated by the fact that the properties and stability field of pPv as estimated from mineral physics remain uncertain.

Here, we investigate the accuracy of different proposed proxies for the presence of post-perovskite, which are all based on global seismic tomography. We utilize synthetic tomography models derived from geodynamic modeling, where we account for our limited tomographic resolution. In particular, we analyse the use of vertical gradients for predicting the depth of the phase transition and we investigate a proxy for pPv lenses based on a heat flow criterion. Finally, we illustrate how tomographic-geodynamic comparisons can potentially be employed to constrain the stability field of post-perovskite in the lower mantle.

*Speaker
†Corresponding author: paula.koelemeijer@univ.ox.ac.uk

[S3-P14] Seismic Investigations into the Edges of the LLSVP under Africa

Harriet Godwin*[1], Paula Koelemeijer[3,2], Karin Sigloch[1], and Tarje Nissen-Meyer[1]

[1]University of Oxford – Department of Earth Sciences, South Parks Road, Oxford OX1 3AN, United Kingdom

[3]University College, Department of Earth Sciences, University of Oxford – Oxford, United Kingdom

[2]Institute of Geophysics, Department of Earth Sciences, ETH Zurich – Zurich, Switzerland

Abstract

Seismic tomography has revealed the presence of two large-low-shear-velocity-provinces (LLSVPs) in Earth's lowermost mantle. These structures exhibit reductions in shear and compressional wavespeed of _˜ 3% and _˜ 1.5% respectively. They cover approximately 30% of the core surface and extend up to 1000 km above the core-mantle boundary. Being such dominant features of the lowermost mantle, the LLSVPs are expected to play an important role in mantle dynamics and to influence interactions between the core and the mantle. Despite being the topic of extensive research, the nature of the LLSVPs is as yet undetermined. They could be hot thermal upwellings or piles of intrinsically dense, chemically distinct material.

While tomography typically delivers a smooth large-scale picture of the Earth's interior, waveform modelling is geared towards assessing waveform effects of localised structures, such as sharp interfaces and small-scale heterogeneities. The detailed seismic structure at the edges of LLSVPs is particularly interesting; the edges appear sharp and are associated with the presence of ultra-low velocity zones. By mapping these small-scale features, we obtain significant insight into the nature of the enigmatic LLSVPs. The location of the boundary of the LLSVP under Africa has been previously studied, but there is little consistency between the results of different studies.

The overall aim of this project is to merge insights from tomography and waveform modelling to form one complete picture of the multi-scale structure at the edges of the LLSVP under Africa. To achieve this, we have set up a new modelling framework using the Born approximation. The Born approximation is used in finite frequency tomography to quantify the sensitivity of a measurement to structure within the Earth. It is a single scattering approximation, which does not take into account the full interaction between wavefield and structure. We will compare synthetic seismograms calculated using this approach to spectral element methods as well as observed data. This will give information about the limitations of the Born approximation, and allow us to mutually interpret results from both tomography and waveform modelling.

We also present observed data from a seismic array in Botswana, which samples the edges of the African LLSVP. We compare the observed data to synthetic seismograms. We analyse the resulting seismograms to determine the effects of sharp edges on the waveforms.

*Speaker

[S3-P15] Thai Seismic Array (TSAR) Project

Satoru Tanaka*[1], Weerachai Siripunvarporn[2], Songkhun Boonchaisuk[2], Sutthipong Noisagool[2], Kenji Kawai[3], Taewoon Kim[4], Yuki Suzuki[3], Yasushi Ishihara[4], Koji Miyakawa[5], Nozomu Takeuchi[5], and Hitoshi Kawakatsu[5]

[1]D-EARTH, JAMSTEC – 2-15 Natsushima-cho, Yokosuka, Japan
[2]Fac. Sci. Mahidol Univ. – Thailand
[3]Grad.Sch.Sci. Univ. Tokyo – Japan
[4]CEAT, JAMSTEC – Japan
[5]ERI Univ.Tokyo – Japan

Abstract

Thailand is located in an important area for teleseismic observations to study the core-mantle boundary (CMB) and the inner core. However, the number of broadband stations has been limited. On the occasion of the KAKENHI project for an innovative area "Core-mantle co-evolution", the Thai Seismic Array (TSAR) project has been started. We have deployed broadband seismographs at 40 sites in the main land of Thailand except for the Malay Peninsula since November 2016 to February 2017. As of today, we have observed several interesting earthquakes occurred in the southwestern Pacific and south America. Our preliminary analysis of Fiji deep earthquakes suggests the existence of a localized very low-velocity region at the base of the mantle and a high-velocity region about 200 km above the CMB below the New Guinea Island.
Acknowledgements
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*Speaker

[S3-P16] Sharp Velocity Gradients in the Earth's Lowermost Mantle Resolved by Wavefield Effects of Multipathing

Jamie Ward*[1], Andy Nowacki[1], and Sebastian Rost[1]

[1]Institute of Geophysics and Tectonics, School of Earth and Environment – Earth Science Building, , Leeds LS2 9JT, United Kingdom, United Kingdom

Abstract

Since their detection by seismic tomography, Large Low Shear Velocity Provinces (LLSVPs) have remained an enigmatic feature of the lower mantle. LLSVPs are continent-size, low velocity features of the lowermost mantle with long-standing uncertainties about their origins and composition. Tomography models have shown the LLSVPs morphology, velocity and location on a large scale, but due to inherent resolution limitations, the finer details of LLSVP structure cannot be extracted. Regional studies of the LLSVP boundary can resolve details such as the angle, location, velocity reduction and sharpness of the boundary by abrupt changes in travel time and the presence of phenomena such as multipathing. Multipathing occurs where the ray path is incident on strong lateral velocity variations over small distances, leading to multiple arrivals when only one is expected. Most previous regional LLSVP studies using multipathing analyse the waveforms only and do not attempt to use the full slowness vector, which gives information about back azimuth and slowness of the arrival. Waves travelling through the LLSVP are expected to arrive with a different slowness and back azimuth relative to waves travelling outside the LLSVP. In this study, we use SKS and SKKS arrivals recorded at temporary arrays in Eastern and Southern Africa sampling inside, outside and across the boundary of the African LLSVP. The slowness vector is recovered using array processing and is used to identify multipathing and recover deviations in absolute slowness and back azimuth. We observe 23% of the events have clear multipathing, with slownesses varying by $\pm 1\circ$/s and back azimuth deviations of up to $\pm 5\circ$. The location of the multipathing shows a more complex pattern of the boundary than the tomography models. Events with no multipathing, that travel through the LLSVP volume, show large back azimuth deviations indicating small volumes with strong lateral velocity variations are embedded in the LLSVP.

*Speaker

[S3-P17] Lateral variation of ultra-low velocity zones beneath the east of Australia using Bayesian inversion of core-reflected phases

Surya Pachhai*[1] and Hrvoje Tkalcic[2]

[1]Scripps Institution of Oceanography (SIO) – University of California San Diego, 9500 Gilman Drive, La Jolla, CA 92093-0208, U.S.A., United States

[2]Research School of Earth Sciences [Canberra] (RSES) – Mills Road, Acton ACT, Canberra, 2601 Australia, Australia

Abstract

Seismic velocity and density estimates of localized small-scale structures such as ultra-low velocity zones (ULVZs) are crucial in understanding physical processes operating in the Earth's lowermost mantle. However, exact quantification of these parameters and their uncertainties is challenging due to strong nonlinearity and non-uniqueness of the inverse problem. In order to ensure rigorous treatment of model parameter values and their uncertainties, we recently developed a Bayesian inversion to study the ULVZs using high-frequency shear (S)-waves and their reflections and conversions to compressional (P) waves from the core-mantle boundary (CMB), known as ScP waves, including reverberations within multiple layers. In this study, we extensively apply this approach to constrain ULVZs beneath the western Pacific area using high quality recordings of ScP waves obtained from short-period transportable arrays in southeast Australia and the Warramunga Seismic array in Northern Territory. The inversion results indicate complex ULVZs, varying in the level of constrained properties, with multiple layers as likely solutions. A common feature in all well-constrained results is that the S-wave velocity decreases with narrow uncertainties and density increases with wider uncertainties as a function of depth. The S- and P-wave velocities decrease by up to 50% and 30%, respectively, whereas density increases up to 30% with respect to the 1-D reference model. These strong perturbations indicate the presence of melt-rich iron material in the lowermost mantle beneath the east of Australia. Furthermore, ULVZ height and velocity vary as a function of the CMB location which implies lateral variability of these structures. In contrast, weakly constrained ULVZs can be due to an insufficient number of waveforms and/or due to the theory errors imposed by an assumption that the ULVZs represent horizontally-layered structures, whereas in reality these features might have more complex shapes and structure. We caution that a simple 1-D forward modeling of ULVZs in which the effects of the data noise are completely neglected may lead to erroneous solutions and interpretations.

*Speaker

[S3-P18] Imaging paleoslabs in the D layer beneath Central America and the Caribbean using seismic waveform inversion

Anselme F. E. Borgeaud*†[1], Kenji Kawai[1], Kensuke Konishi[2], and Robert J. Geller[1]

[1]Department of Earth and Planetary Science, School of Science, University of Tokyo – Japan
[2]Institute of Earth Sciences, Academia Sinica – Taiwan

Abstract

D, the lowermost layer of the Earth's mantle, is the thermal boundary layer (TBL) of mantle convection immediately above the Earth's liquid outer core. As the origin of upwelling of hot material and the destination of paleoslabs (downwelling cold slab remnants), D plays a major role in the Earth's evolution. D beneath Central America and the Caribbean is of particular geodynamical interest, since the paleo- and present Pacific plates have been subducting beneath the western margin of Pangaea since _˜250 Ma, which implies that paleoslabs could have reached the lowermost mantle. We conduct waveform inversion using a dataset of _˜7,700 transverse component records cut around the direct S- and ScS waves at epicentral distances between 70-100 to infer the detailed 3-D S-velocity structure in the lowermost 400 km of the mantle in the study region, so that we can investigate how cold paleoslabs interact with the hot TBL above the core-mantle boundary (CMB). We can obtain high-resolution images because the lowermost mantle here is densely sampled by seismic waves due to the full deployment of the USArray broadband seismic stations during 2004-2015. We find two distinct strong high-velocity anomalies, which we interpret as paleoslabs, just above the CMB beneath Central America and Venezuela, respectively, surrounded by low-velocity regions. Strong low-velocity anomalies concentrated in the lowermost 100 km of the mantle suggest the existence of chemically distinct denser material connected to low velocity anomalies in the lower mantle inferred by previous studies, suggesting that plate tectonics on the Earth's surface might control the modality of convection in the lower mantle. We present several resolution and robustness tests to show that localized waveform inversion can infer the detailed structure of the lowermost mantle.

*Speaker
†Corresponding author: anselme@eps.s.u-tokyo.ac.jp

[S3-P19] Core-mantle dynamic topography and the thermo-chemical structure of the lowermost mantle

Frédéric Deschamps*[1], Yves Rogister† , and Paul Tackley‡[2]

[1]Institute of Earth Sciences, Academia Sinica – 128 Academia Road, 11529, Taipei, Taiwan
[2]Institut für Geophysik (ETHZ) – ETH Zürich, Sonneggstrasse 5, Zürich, CH-8092, Switzerland, Switzerland

Abstract

Mantle flow induces dynamic topography at the core-mantle boundary (CMB), with distribution and amplitude that depend on the properties of the flow. To assess whether observations of CMB topography can give constraints on deep mantle structure, we determine dynamic topography induced at the CMB by different models of mantle convection, including thermo-chemical and purely thermal models. More specifically, we investigate the influence of key controlling parameters, in particular the thermal viscosity ratio ($\Delta\eta$T) and, for thermo-chemical models, the chemical density contrast ($\Delta\rho$C) and chemical viscosity ratio ($\Delta\eta$C) between primordial and regular materials. In purely thermal models, plume clusters induce positive topography with an amplitude that decreases with increasing $\Delta\eta$T. In thermo-chemical models with moderate density contrasts, around 100-200 kg/m3, reservoirs of dense material induce depressions in CMB topography, surrounded by a ridge of positive topography. The average depression depth and ridge height increase with increasing $\Delta\rho$C and $\Delta\eta$C, but decrease with increasing $\Delta\eta$T. We find that for purely thermal models or thermo-chemical models with $\Delta\rho$C ˜90 kg/m3 and less, the long-wavelength (spherical harmonic degrees up to $l = 4$) dynamic topography and shear-wave velocity anomalies predicted by thermo-chemical distributions anti-correlate. By contrast, for models with $\Delta\rho$C $\geq$ 100 kg/m3 and $\Delta\eta$C $>$ 1, long-wavelength dynamic topography and shear-wave velocity anomalies correlate well. This potentially provides a test to infer the nature, i.e. either purely or mostly thermal ($\Delta\rho$C $\leq$ 100 kg/m3) or strongly thermo-chemical ($\Delta\rho$C $\geq$ 100 kg/m3), of the low shear-wave velocity provinces observed by global tomographic images. The presence of post-perovskite, provided that its viscosity is similar to that of bridgmanite, does not alter these conclusions.

*Speaker
†Corresponding author: yves.rogister@unistra.fr
‡Corresponding author: paul.tackley@erdw.ethz.ch