High-resolution mapping of seismic properties across upper mantle discontinuities in the stagnant slab region beneath Korea

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Plate tectonic processes operating over much of the Earth’ s history induce long-term mantle mixing of chemical heterogeneities, recycling of volatiles into the mantle and regulate basalt geochemistry. Fundamental questions relevant to the mantle transition zone concern the nature of phase transition, the distribution of chemical heterogeneities (e.g., harzburgite, basalt), the temperature gradient, as well as the degree and extent of hydration and melting. One particularly important question is how the slab stagnation may be influenced by hydration or/and basalt enrichment in the mantle transition zone. To help answer these questions, we aim to detail upper mantle seismic discontinuity properties, including the shear velocity contrast, the density contrast, the transition sharpness and the gradient using high-quality receiver functions using broadband data in South Korea, which is located in the immediate vicinity of the imaged stagnant slab near northeast China.

Our approach involves broadband observation and amplitude analysis of direct converted waves (Pds) and multiples (PpPds) from the 410 and 660 seismic discontinuities, following our previous effort in a similar analysis in China. We processed waveforms from available broadband seismic stations of the Korea seismic array using an automatic scheme to remove noisy waveforms and retained close to ~12,000 high quality receiver functions. After gathering receiver functions as a function of epicentral distance, we perform slowness stacking of direct converted waves and the multiples, respectively, at several discrete frequency bands between 1 sec and 15 sec.. To avoid interferences from other mantle waves (PP, PPP, PcP, PP410s, PP660s), we stack receive functions across epicentral distances of 74-90 (62-76) degrees for the 410 (660) seismic discontinuity and obtain amplitude estimates and uncertainties through the bootstrap method. To properly calibrate the amplitudes of receiver functions, we take into account the effect of incoherent stacking due to discontinuity topography and frequency-dependent attenuation. Preliminary result will be presented and contrasted against our previous work in east China.

Keywords: transition zone, receiver function

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Imaging topography of 410km and 660km discontinuities in eastern North China Craton from ambient noise interferometry

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A sudden increase of both elastic wavespeeds and densities has been indicated near 410km and 660km depth, which are both interpreted as phase changes in the olivine system induced by pressure and temperature changes. And lateral variations of temperature and composition would lead to local topographic changes of both discontinuities. Usually, Ps and Sp conversions, SS precursors, and reflections of local high-frequency subduction zone earthquakes are utilized to study the regional or global topography of mantle discontinuities and the thickness of mantle transition zone. Here we present how to image the mantle transition zone discontinuities in eastern North China Craton with ambient noise interferometry. In the last decade, ambient noise correlation technique has made rapid developments and is increasingly used to extract body wave signals between receiver pairs, which are then used to explore the Earth’s interior structures. More correlations need to be stacked to improve the signal to noise ratio of retrieved body waves than surface waves due to their weaker amplitude. Hence, it is still difficult to obtain high-resolution topographic images of 410km and 660km discontinuities from ambient noise interferometry. In this research, about two years long continuous vertical component records of a dense array (~200 stations) deployed in eastern North China Craton were used to calculate ambient noise cross-correlations. All the cross-correlations were corrected to the zero-offset traces by removing the time delay caused by the inter-station distance as well as 3-D lateral heterogeneities using 3-D velocity models. Then the study area was divided into a grid network and each grid point was regarded as the center of a circle bin. And all the corrected cross-correlations were stacked using a phase-weighted stacking method if their reflection points (the middle points of station pairs) are located within the same bin. And all the stacked traces within each bin were used to map the topography of mantle discontinuities. The result determined by the reflected P phases extracted from ambient noise interferometry was compared with that determined by teleseismic Ps conversions at the same region. Both results indicate shallower depth of 410km discontinuity in the northeastern part of the study region, however, deeper depth in the southwestern part. The overall pattern of the topography of 660km discontinuity is similar with 410km discontinuity but more complicated. Both studies reveal thinner transition zone beneath Taihang Mountain area, possibly implying higher temperature caused by small-scale mantle upwelling. The similarity between the results from these two methods proves the reliability of this interferometric method. In addition, relative amplitude ratios between the 410km and 660km reflected P phases vary in different regions, which implies lateral changes of phase transition thickness of these two discontinuities.

Keywords: Ambient noise interferometry, Mantle discontinuities, Body waves

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The Impact of the Iron Spin-transition on Seismic Signatures in Bullen's C-Layer

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Bullen's C-Layer lies between 660 km and 1200 km and has distinctive signatures characterized by discontinuities which may have geodynamical origins. The high-spin to low spin transition of Fe^{++} in iron-magnesium oxides in the lower mantle is a second-order phase transition which causes changes in the density, and elastic properties. They are likely to occur below ~1200 km depth with the highest degrees of influence at about 1800 km depth, depending on the local temperature conditions. We have investigated the dynamical consequences with a compressible spherical convection model, where this transition has been included. Depending on the magnitude of this second-order transition, the sinking slabs may be stagnated at mid mantle depths (~1600 km) or be slowed at the shallower depths. Similarly the rising plumes can be stagnated below ~1600 km depth; resulting a layered convection in the lower mantle. Our results show the potential importance of the high-spin to low spin transition in creating visible seismic signatures in the Bullen’ s C-layer and the D-layer.

Keywords: iron spin transition, mantle mixing, slab stagnation

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Oceanic crust-like structures in the mid-mantle below subduction zones seen by source-sided S-to-P conversions.

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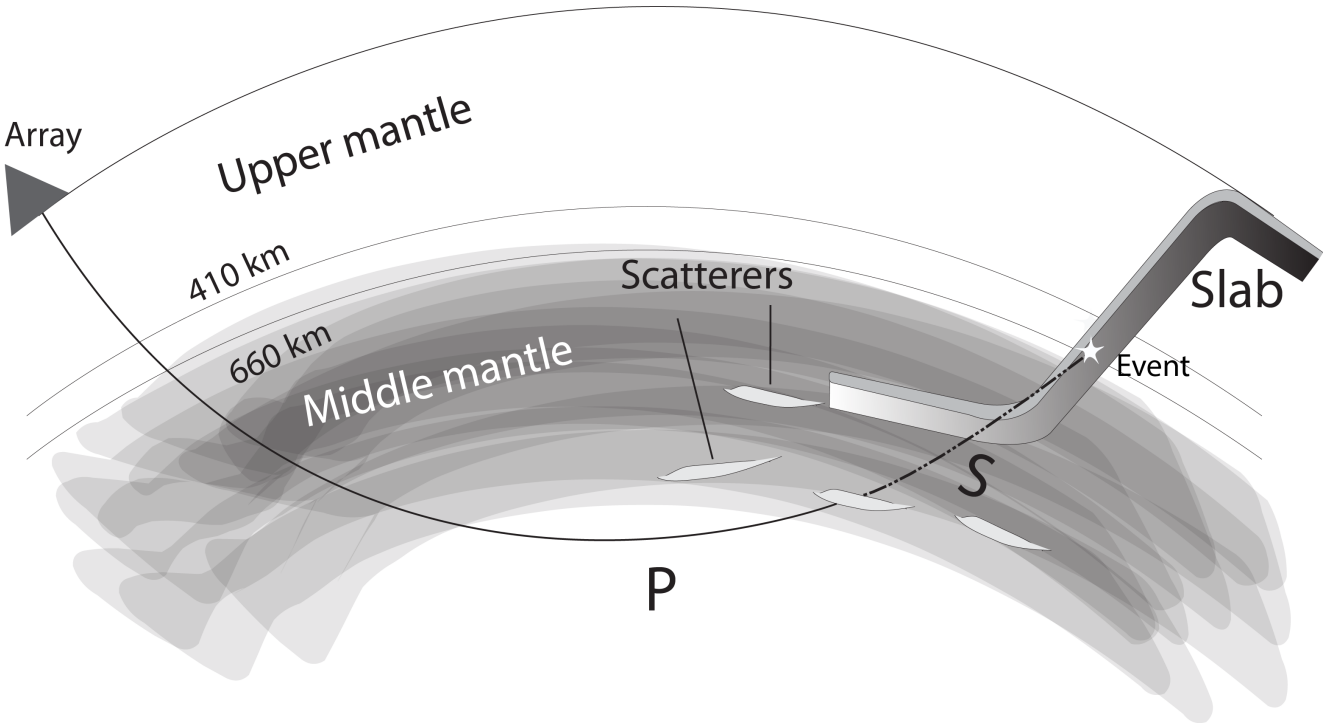
The fate of a subducted slab is a key ingredient in the context of plate tectonics, yet it remains enigmatic especially in terms of its crustal component. In this study, our efforts are devoted to resolve slab-related structures in the mid-mantle below eastern Inonesia, the Izu-Bonin area, and the Solomon-Tonga region by employing seismic array analysing techniques on high frequency waveform data from F-net in Japan, the Alaska regional network in North America and NECESSArray in Northeast China. A pronounced arrival after the direct P wave is observed in the recordings of eight deep earthquakes (greater than 400 km) mostly sourced from western Pacific subduction systems. This later arrival displays a slightly lower slowness compared to the direct P wave and its back-azimuth deviates somewhat from the great circle direction. We explain it as an S-to-P conversion at a deep scatterer below the sources in the earthquake regions. In total nine scatterers are seen at depths ranging from ~700-1110 km. Our waveform forward modelling reveals that those scatterers are characterized by an ~ 7 km thick low-velocity layer compared to the ambient mantle. Combined evidence from published mineral physical analysis suggests that past subducted oceanic crust, possibly fragmented, is most likely responsible for these thin-layer compositional heterogeneities trapped in the mid-mantle beneath the study regions.

Keywords: Oceanic crust, Seismic array, S-to-P conversions, mid-mantle



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Discontinuity image of the upper mantle transition zone beneath eastern and southeastern Tibet

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We present new constraints on the upper mantle transition zone structure beneath eastern and southeastern Tibet based on P-wave receiver functions for a large broadband data set from two very dense seismic arrays. The northern array, installed during 2007 to 2009, consisted of 288 broadband stations spaced at 10–30 km intervals, mainly across the Qiangtang and Songpan-Ganzi blocks and the Sichuan Basin. The southern array consisted of 350 broadband stations with an average spacing of ~35 km, and was deployed mainly in SE Tibet by the ChinArray project from 2011 to 2014. To apply the receiver function technique, we collected events with body wave magnitudes > 5.0 and at epicentral distances of 30–90°. We computed a dataset of 195,000 high-quality receiver functions from 1,360 teleseismic events. Our results show a clear depression of both the 410-km and 660-km discontinuities west of the Red River fault relative to the east. The same amount depression of the two discontinuities results in a normal transition zone beneath the Tengchong volcano. Moreover, a significant depression of the 660-km discontinuity is detected beneath the western Yangtze Craton. In contrast, that the transition zone thickness beneath much of the Sichuan Basin is similar to the global average. These result not only provide new constraints on the mechanism of the Tengchong volcano but also shed light into the depth extent of the Red River fault and the possible presence of detached lithosphere below the western Yangtze Craton, which are key to understanding the tectonic evolution of eastern and SE Tibet.

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Keywords: Tibet, receiver function, Red River fault zone, Tengchong volcano

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