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Difference in seismic velocity between the eastern and western hemispheres in the top of the earth's inner core

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With 2 figures in the text

ABSTRACT

PKiKP and PKIKP phases at distances of 120–142 degrees are used to study the seismic structure of the uppermost 100 km of the inner core. The travel time residuals and waveforms of PKiKP and PKIKP clearly reveal a difference in seismic velocity and Q structure between the "eastern hemisphere" (40° E – 180° E) and the "western hemisphere" (180° W – 40° E). The "eastern hemisphere" has faster isotropic velocities (about 0.8% faster) and higher attenuation compared to the "western hemisphere".

1. Introduction

Knowledge of the seismic structure at the top of the Earth's inner core is important to the understanding of the physical process of the inner-core growth. Unfortunately, there remains no systematic study of global seismic structure in the top 100 km of the inner core, although results from waveform modelling of regional data are available in some regions. By using the differential travel-time between PKIKP (PKPdf) and PKP (bc) phases, all previous global (Tanaka & Hamaguchi, 1997; Creager, 1999) studies are focused on the seismic structures 100 km below the inner-outer core boundary. From seismological point of view, detailed seismic structures at the top of the inner core are also essential, as the lack of their knowledge might well affect our conclusions about the deep seismic structures.

2. Data and methods

We systematically study the seismic structure at the top of the inner-core using the differential travel time and waveform of the PKiKP and PKIKP phases recorded globally at a distance range of 120–142 degrees. PKiKP is the P wave reflected off the inner core boundary and PKIKP is the P wave propagating through the inner core. The differential travel time between these two phases is most sensitive to the seismic structure in the top of the inner core, as they have almost identical ray paths in the mantle at the distance range of 120–142 degree. We collect a total of 345 PKiKP and PKIKP travel times from many regional seismic arrays and the IRIS global seismic network (GSN).

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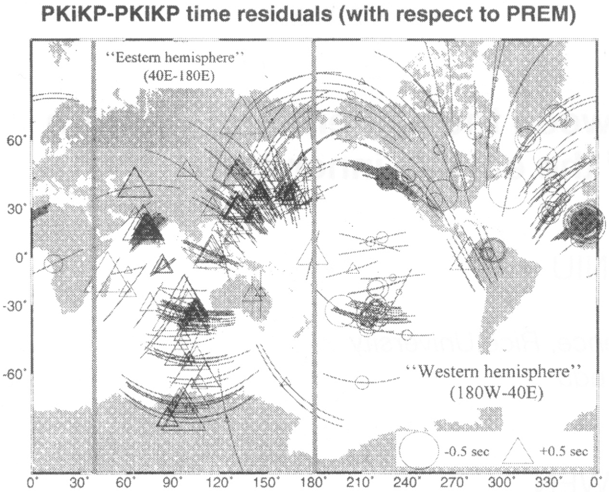

Fig. 1. Map view of PKiKP minus PKIKP travel time residuals displayed as lines along ray segments through the inner core and as symbols at the turning points. The residuals are calculated with respect to the PREM. Circles and triangles represent negative and positive residuals, respectively. The size of the symbols is proportional to the absolute value of residuals.

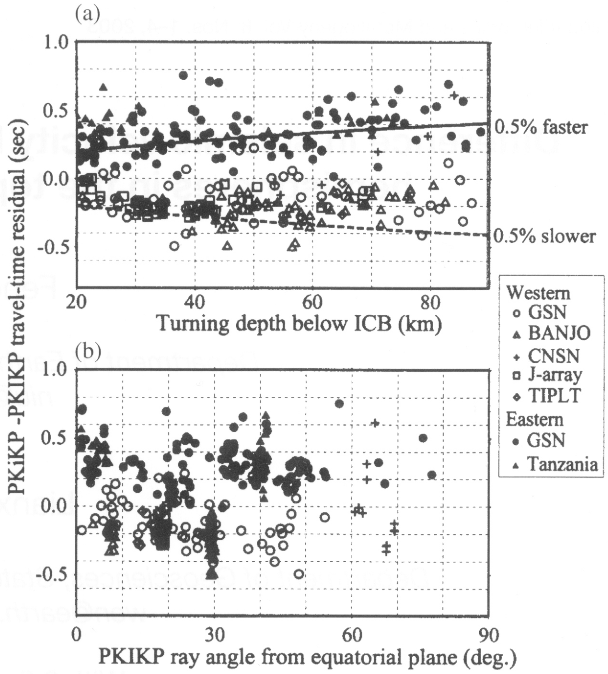

Fig. 2. Travel time residuals of PKiKP-PKIKP as a function of: (a) PKIKP turning depth below the ICB; (b) PKIKP ray angle from equatorial plane. Solid and open symbols represents the "eastern" and the "western" hemispheres, respectively. The predicted time residuals of PKiKP-PKIKP for two models with a top 100 km layer 0.5% faster and slower than the PREM in the inner core are shown by a solid and a dotted lines, respectively.

3. Observation and results

Differential travel time residuals of PKiKP-PKIKP show a clear difference between "eastern hemisphere" and the "western hemisphere" (Fig. 1). A positive (negative) travel time residual indicates a relatively higher (lower) seismic velocity in the top of the inner core compared to the PREM model (Dziewonski & Anderson, 1981).

The travel time residuals of PKiKP-PKIKP are found to be systematically larger (about 0.8 seconds) in "the eastern hemisphere" (40° E – 180° E) than those in "the western hemisphere" (Fig 1). These travel time residuals, on the other hand, show no correlation with the angles which the PKIKP phases sample the inner-core, indicating that these residuals are caused by the isotropic seismic heterogeneities in the outermost 100 km of the inner-core (Fig. 2).

The observed hemispherical distribution of PKiKP-PKIKP time residual cannot be explained by the heterogeneities near the core-mantle boundary. Because the Fresnel zones of PKiKP and PKIKP (about 150 km) overlay, the heterogeneities near the CMB would affect both phases in the same way. As the result, the heterogeneities at the CMB would have little effect on the differential travel time of these two phases. Furthermore, some regions of the core-mantle boundary (for example, Tonga, Europe) are sampled by both rays bottoming in different "hemispheres".

The systematic variation of these differential travel times can also unlikely be explained by variation of the inner core radius. An increase or decrease of the inner core radius at both the piercing points of PKIKP rays and the reflection points of PKiKP rays would have almost no effect on PKiKP-PKIKP time. Small scale topography, which may affect these two phases differently, also is unlikely the explanation to our observation, because the piercing points of PKIKP rays and the reflection points of PKiKP rays at the ICB overlap in some regions (i.e. western Pacific).

The PKiKP-PKIKP time residuals thus can only be attributed to the heterogeneity within the inner core. The travel time residuals observed in the „eastern hemisphere" can be fit by a model with P velocities roughly 0.5% faster than the PREM in the top 100 km of the inner core, whereas those observed in the „western hemisphere" can be explained by a model with P velocities 0.3% slower than the PREM.

Meanwhile, waveform modeling suggests that "the eastern hemisphere" has a lower Q compared to the "western hemisphere". We suggest that the hemispheric distribution of seismic heterogeneities might be caused by a large-scale heat flow anomaly at the bottom of the outer core (Sumita & Olson, 1999) and/or convection within the top of the inner core.

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