Available online at www.sciencedirect.com
ScienceDirect
Earth and Planetary Science Letters 259 (2007) 486–499
EPSL
www.elsevier.com/locate/epsl

Possibility of a low *P*-wave velocity layer in the outermost core from global *SmKS* waveforms

Satoru Tanaka *

Institute for Research on Earth Evolution (IFREE), Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 2-15 Natsushima-cho, Yokosuka 237-0061, Japan

Received 21 June 2006; received in revised form 23 January 2007; accepted 6 May 2007
Available online 10 May 2007
Editor: R.D. van der Hilst

Abstract

A global data set consisting of 1211 *SmKS* ($m \geq 2$) waveforms has been analyzed to investigate the radial seismic velocity structure around the core–mantle boundary (CMB). Band-passed (f=0.02–0.1 Hz) and stacked waveforms coincide with reflectivity synthetic ones for PREM very well, whereas those for other global models (*iasp91*, *ak135*, and *SP6*) yield disagreements. A preliminary waveform modeling for the outermost core with PREM as initial structure results in a core surface layer with a *P*-wave velocity of 7.95 km/s at the core top and thickness of 90 km. Based on a 3-D global *S*-wave velocity model, *SmKS* phases collected in this study mainly pierce slightly high velocity regions at the base of the mantle, and the predicted differential travel time residuals for *S3KS-SKKS* are expected to be negative, approximately −0.5 s for the averages. However, positive *S3KS-SKKS* residuals, of which average is +0.3 s, are predominant in the stacked waveforms. Moreover, a waveform modeling for the D″ structure can result in a 30 km thick layer with a 10% *S*-wave velocity reduction at the mantle bottom (ULVZ), in which waveform fitness for the part of mainly *S3KS* is improved. On the other hand, the waveform data is not well explained by the lowermost mantle structures with thickness of several hundred kilometers. These suggest that the *SmKS* data is still affected by the structure of the lowermost several tens kilometers in the mantle that is not sufficiently modeled by a global tomography. Although the thin low *S*-wave velocity model is not conclusive, the possibility of a low *P*-wave velocity layer in the outermost core is remained because the waveform fitness for the part of *S4KS* is improved by the combination of the ULVZ and a 140 km thick layer with a 0.8% *P*-wave velocity reduction at the core top.

Keywords: the outermost core; a low-velocity layer; *SmKS* phases

1. Introduction

The top of the Earth's outer core is one of the frontiers which is not as precisely known as the mantle-side of the core–mantle boundary (CMB) (Loper and Lay, 1995). Geophysical speculations have been discussed on a stably stratified layer of approximately 100 km thickness beneath the CMB. The layer is important for understanding the core flow associated with the geodynamo and the thermal coupling at the CMB. For example, the existence of a stratified layer is hypothesized from the coupling of the Earth rotation and geomagnetic secular variations

* Tel.: +81 46 867 9340; fax: +81 46 867 9315.
E-mail address: stan@jamstec.go.jp.

0012-821X/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.epsl.2007.05.007

(Braginski, 1993, 1999). Its implications are discussed for the thermal and compositional evolution of the core (Lister and Buffett, 1998). Unfortunately, many researchers have been pessimistic about the seismological detection of this layer because the density variation is expected to be too small (Stevenson, 1987). Furthermore an exact seismic structure of the top of the outer core has been controversial for long years although a relatively low-velocity layer has been frequently proposed (Hales and Roberts, 1971; Lay and Young, 1990; Souriau and Poupinet, 1991; Kohler and Tanimoto, 1992; Garnero et al., 1993; Tanaka and Hamaguchi, 1993a; Garnero and Helmberger, 1995; Souriau et al., 2003; Tanaka, 2004).

The upper part of the outer core has been examined using *SKS* and *SmKS* ($m \geq 2$) seismic phases (Fig. 1a), which propagate in the mantle beneath a source and a receiver as *S*-waves, are converted to *P*-waves in the outer core denoted as *K*, and reflected ($m-1$) times under the CMB. When we consider a global structure, PREM (Dziewonski and Anderson, 1981) is frequently used as a reference. In PREM, the seismic velocity and density structures of the core are constrained by *SKS* travel times and by free oscillation data under the assumption of adiabaticity and homogeneity. Recent global models, *iasp91* (Kennett and Engdahl, 1991), *SP6* (Morelli and Dziewonski, 1993), and *ak135* (Kennett et al., 1995; Montagner and Kennett, 1996) include *SKS* and *SKKS* travel times to improve the velocity structure in the outermost core. They use *SKKS*-*SKS* differential travel times measured by Hales and Roberts (1971) or *SKKS* travel times that are taken from the Bulletin of the International Seismological Centre (ISC). However, the reliability and/or quality of those data sets are quite questionable (Choy, 1977). On the other hand, the previous waveforms studies using *SKS*, *SKKS*, and supplementary *S3KS* were able to use only a small number of seismic stations that were sparsely distributed on the Earth (Souriau and Poupinet, 1991; Tanaka and Hamaguchi, 1993a). However, *SKKS*-*SKS* times have been recently utilized for small-scale heterogeneity and/or lateral variation of anisotropy in the lowermost mantle because the ray distance between the two phases at the base of the mantle is not so close to each other (Sylvander and Souriau, 1996; Liu and Dziewonski, 1998; Garnero and Lay, 1998; Tanaka, 2002; Niu and Perez, 2004; Restive and Helffrich, 2006). In order to improve the resolution of the outermost core, detailed waveform studies using the combination of *SKKS*, *S3KS*, and *S4KS* observed by a dense seismic network have been conducted but restricted to a regional investigation (Garnero et al., 1993; Tanaka, 2004; Eaton and Kendall, 2006). Difficulty for removing a bias from radial and lateral heterogeneities in the lower

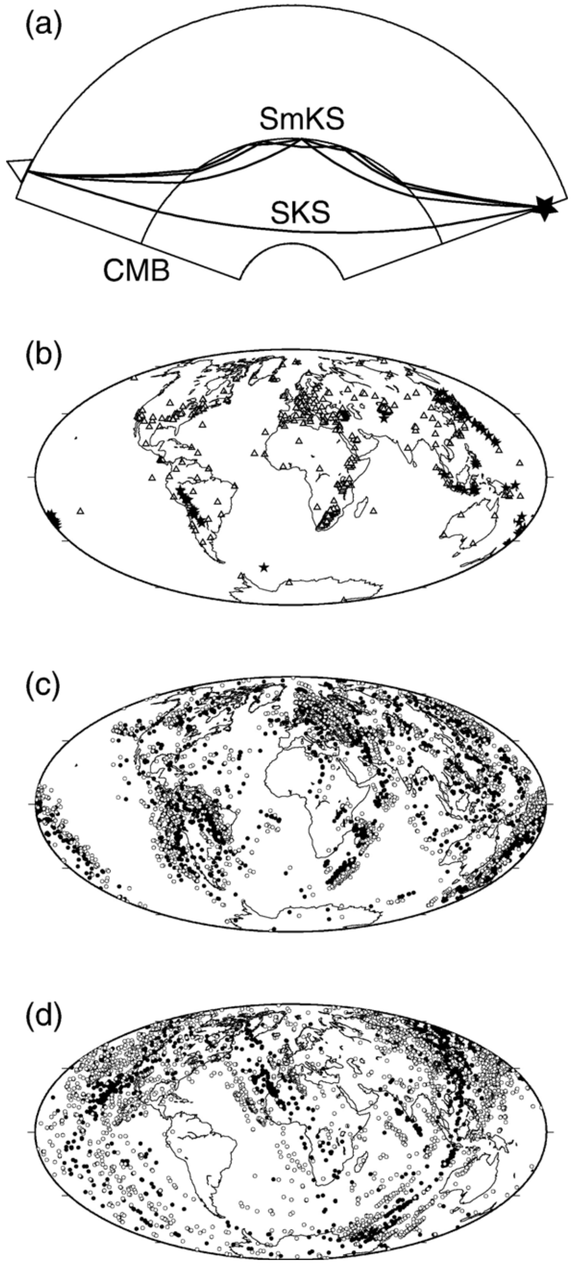

Fig. 1. (a) Typical ray paths for *SKS* and *SmKS* (m=2, 3, 4) phases from a deep event (a solid star) to a seismic station (an open triangle). Geographical distributions for (b) 87 epicenters (solid stars) and 442 stations (open triangles) used in this study, (c) piercing points of *SKKS* (solid circles) and *S3KS* (open circles) at the CMB, and (d) reflection points of *SKKS* (solid circles) and *S3KS* (open circles) under the CMB. Hammer projection is used.

mantle is also pointed out even if *S3KS*-*SKKS* and *S4KS*-*S3KS* are used (Garnero and Helmberger, 1995). Moreover a global tomographic model does not always explain the differential travel time residuals of *S3KS*-