Seismic velocity structure at the top of the Earth's outer core from broadband seismic array analysis of SmKS phases

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The core-mantle boundary (CMB) has been usually discussed on the basis of the anomalies at the base of the mantle. The strong heterogeneity at the base of the mantle has prevented investigating the fine structure at the top of the Earth's outer core. However, the issues of stable stratification and possible heterogeneity at the top of Earth's outer core are important to understand not only the core-mantle interaction but also the dynamics of the outer core. Therefore, some seismological studies had previously tried to reveal the structure of the region using the seismological networks belonging to the former generations such as the WWSSN and GDSN, but their results were not consistent each other (e.g. Souriau and Poupinet, 1990; Lay and Young, 1990; Kohler and Tanimoto, 1992; Tanaka and Hamaguchi, 1993, Garnero et al., 1993). The recent data accumulation under the modern seismic networks or arrays consisted of broadband seismographs makes it possible to try a further study. Here I show the results of the analysis using the Kaapvaal broadband seismic array in 1997-1999 (James et al., 2001), and Tanzanian array in 1994-1995 (Nyblade et al., 1996). The target of analysis is SmKS ($m = 2, 3, 4$) seismic phases. Seismograms were deconvoluted using the instrumental response to displacement, and rotated the horizontal components into the radial ones, and normalized with each maximum amplitude. The relative times were corrected to align on the peak locations of S2KS or S3KS. I applied the phase-weighted stack (Schimmel and Paulssen, 1997) to separate the SmKS phases in the time-slowness space and the Bootstrap method (Efron and Tibshirani, 1998) for error estimation. The peak location of S3KS was picked on the 50 vespagrams from the bootstrap sampling of the displacement seismograms while the Hilbert transformed displacement seismograms were used for picking S2KS and S4KS because of the phase shift of the SmKS. I got the averagaes and the standard deviations of the measurements. I have analyzed the array records of two shallow depth earthquakes (1994/10/01, 1997/05/21 in Vanuatu), one intermediate-depth earthquakes (1997/04/23 in Mariana), and three deep earthquakes (1997/09/04 in South Fiji; 1998/01/27 in South Fiji; 1998/03/29 in Fiji). The ray paths are distributed under the Indian Ocean, and cross the CMB regions with the small velocity perturbation found in the Harvard model of S16U6L8 (Liu and Dziewonski, 1998). Main areas of the Fresnel zones between S(m+1)KS and SmKS phases at the CMB coincide for the predominant period of 10 s. Thus the effect of the lower mantle heterogeneity is expected to be reduced very much by taking the difference of two phases. Differential travel times and relative slowness were obtained for the combination of S2KS and S3KS from all the 6 events, and those for S3KS and S4KS were from only the deep event on 1998/03/29. PREM was used for the calculation of the ray theoretical travel times and slowness as a reference at the reference epicentral distance. The residuals of T(S3KS-S2KS) show a systematic variation as a function of the epicentral distance as 0.5 +-0.3 s (122.0 degrees), 0.9 +-0.6 (122.5 degrees), 0.8 +-0.3 (122.5 degrees), 0.3 +-0.3 s (126.6 degrees), 0.2 +-0.6 (128.0 degrees),0.2 +-0.1 s (130.8 degrees). The residual of T(S4KS-S3KS) at about 131.5 degrees was 0.0 +- 0.1 s while the residual slowness was +0.4 s/deg. A low velocity layer locating from 50 to 150 km below the CMB can explain this residual variation. Through trial and error, I found that the maximum velocity reduction in the layer is 0.4 % at approximately 100 km below the CMB.