Finite frequency effects on the S wavefields in the lowermost mantle for elastic and density models based on mineral physics

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The lowermost mantle (D” region) is the thermal and chemical boundary layer of the mantle convection. Previous studies using the traveltime of seismic wave have inferred the seismic velocity structure and revealed the large-scale heterogeneity in the lowermost mantle where the large low velocity provinces beneath the Pacific and Africa are surrounded by high velocity anomalies (e.g., Grand 2002). Because the chemical heterogeneity is considered to exist in D” (e.g., Masters et al. 2000), it has been controversial whether the velocity anomalies are due to thermal variation, chemical heterogeneity, or both. Therefore, it is important to infer the density structure in D” in order to better understand the thermal and chemical evolution of the mantle. Although traveltimes provide information only on velocity structure due to ray approximation, seismic waveforms include other information on elastic and/or anelastic properties such as density and Q. Therefore, in this study we investigate finite frequency effects on the wavefields in D” for elastic models including density and Q based on mineral physics.
We consider four different temperature profiles with thicknesses of the thermal boundary layer (TBL) of 50, 100, 250, and 400 km and compute the associated P and S velocity and density models by using the thermoelastic data (Wentzcovitch et al. 2006; Tsuchiya and Tsuchiya 2006) following Kawai and Tsuchiya (2009) and the associated Q models assuming Arrhenius exponential law (e.g., Minster and Anderson 1981). Then, we compute synthetic seismograms for four different TBL thicknesses using the DSM (Kawai et al. 2006) and investigate the finite frequency effects on wavefield in D”. First, we find the phases with amplitudes times about 0.2 which are not predicted by ray theory about 10 s after the ScS (or Sdiff) for radial component especially for TBL thickness of 50 and 100 km. This phase might provide information on the density variation in D” especially for the cold regions. Second, we find the larger attenuation of the triplicated S-phase turning inside the D” layer for the thicker TBL models associated with hot regions, leading to the possibility that low amplitude of direct phases might be overlooked and larger amplitude later phases might instead incorrectly be picked as the direct arrival (Borgeaud et al. 2016). Therefore, taking effects of Q into account, the anisotropy in D” will be more difficult to be estimated by using the S wave splitting data. Hence, the finite frequency effect on the wavefield investigated in this study will contribute to better understanding the thermal and chemical evolution of the lowermost mantle.

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