The finite frequency effects under Japan estimated from broad-band teleseismic waveforms

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In most previous tomographic studies, seismic ray theory is used which assumes the propagation path of body waves to be an infinitely thin ray. Recent studies suggest that seismic waves have finite frequency bandwidths and are sensitive to three dimensional (3-D) structure off the geometric ray path (e.g., Dahlen et al., 2000). This theory is called Banana-Doughnut theory named after a hollow banana-shaped region of seismic wave propagation. Recently this new theory has been used to conduct tomographic inversions (e.g., Montelli et al., 2004; Hung et al., 2004). But, there have been some debates on the validity of the new theory and its applicability to tomographic inversions.

In this study, we have tried to investigate whether the effects of finite-frequency can be observed from the observed waveforms and how large they are if observable. We have measured about 10,000 P-wave relative travel time residuals in short-period, intermediate-period, and long-period windows from the broadband seismograms of 71 teleseismic events recorded by the F-net seismic network in Japan by using the multi-channel cross-correlation method (VanDecar and Crosson, 1990).

Our results show that relative travel time residuals of different periods are similar in general and they can be well explained by the 3-D upper mantle structure of Japan. In most cases, their differential times are smaller than the picking errors in this analysis (0.1-0.2 sec). At some stations, however, the time differences are up to 0.72 sec, which are larger than the picking errors. Some significant differences in the distribution of the relative residuals between different period windows are observed, which suggests that seismic waves of different periods are sensitive to different scales of structural heterogeneities, such as the subducting slabs, magma chambers, fault zones, and cracks, etc.