The geographic variation of upper-crustal structure well-determined by Ekstrom’s (2017) maps of 5s period Rayleigh wave phase velocity $v_R$. This structure reflects geographically-varying upper crustal lithologies, and especially sediment thickness. We develop a formula for estimating the teleseismic P and S wave vertical travel time ($T_P$ and $T_S$, respectively) associated with upper crustal structure in a region with 5s Rayleigh wave phase velocity $v_R$. We use a simple crustal model with an upper crust, a lower crust, and a half-space mantle (Figure 1A). The upper crust has fixed thickness $H_1 = 8$ km, density $\rho_1 = 2000$ km/m$^3$ and compressional-to-shear velocity ratio $v_{p1} = 1.78v_{s1}$ and variable compressional velocity $v_{p1} = v$. The lower crust ($H_2 = 30$ km, $\rho_2 = 2500$ km/m$^3$, $v_{p2} = 1.78v_{s2}$) and mantle half-space ($\rho_3 = 3000$ km/m$^3$, $v_{p3} = 1.80v_{s3}$) are fixed. Forward modeling in this crustal model is used to predict the Rayleigh waves velocity $v_R(v)$ and the vertical travel times $T_P(v)$ and $T_S(v)$. We vary $v$ to build up sets of ($T_P, v_R$) and ($T_S, v_R$) data and use least-squares to fit a cubic curve to them, obtaining smooth functions $T_P(v_R)$ and $T_S(v_R)$ (Figure 1B). Finally, we evaluate these functions for each point in Ekstrom’s (2017) model of $v_R$ to build geographically-gridded estimates of $T_P(v_R)$ and $T_S(v_R)$. These gridded estimates can be interpolated to yield $T_P$ and $T_S$ at a particular geographic location.

![Figure 1](image)

**Figure 1.** A. (left) Earth model. B. (right) Exact (circles) and fit (solid lines) vertical P and S wave travel times $T_P(v_R)$ (red) and $T_S(v_R)$ (green) as a function of 5s Rayleigh wave phase velocity $v_R$.

The vertical travel times through the upper crust are:

$$T_P(v_R) = \left(\frac{8}{5.6}\right) + \Delta T_P(v_R) \quad \text{and} \quad T_S(v_R) = \left(\frac{8 \times 1.78}{5.6}\right) + \Delta T_S(v_R)$$

$$\Delta T_P(v_R) = (6.2263) + (-5.1800)v_R + (1.5451)v_R^2 + (-0.1687)v_R^3$$

$$\Delta T_S(v_R) = (11.0828) + (-9.2204)v_R + (2.7503)v_R^2 + (-0.3003)v_R^3$$

These formulas, evaluated for Ekstrom’s (2017) data are shown in Figures 2 and 3.

Fig. 2. P wave vertical travel time perturbation $\Delta T_P$

Fig. 3. S wave vertical travel time perturbation $\Delta T_S$