Travel Time Correction Teleseism P and S waves for Upper Crustal Structure
Bill Menke, 9/16/2019

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 $\rho_1 = 2000\,\mathrm{km/m^3}$ and compressional-to-shear velocity ratio $v_{P1} = 1.78 v_{S1}$ and variable compressional velocity $v_{P1} = v$. The lower crust ($H_2 = 30$ km, $\rho_2 = 2500\,\mathrm{km/m^3}$, $v_{P2} = 1.78 v_{S2}$) and mantle half-space ($\rho_3 = 3000\,\mathrm{km/m^3}$, $v_{P3} = 1.80 v_{S3}$) 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.

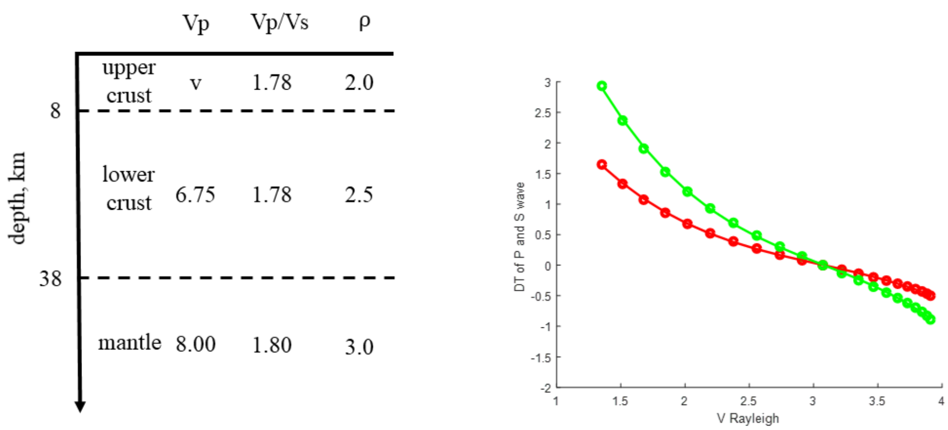

Figure 1. A. (left) Earth model. B. (right) Exact (circles) and fit (solid lines) vertical P and S wave travel times $T_P(v_R)$ (red) and $T_S(v_R)$ (green) as a function of 5s Rayleigh wave phase velocity v_R.

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.

Reference: Ekström, G., 2017. Short-period surface-wave phase velocities across the conterminous United States, Physics of the Earth and Planetary Interiors 270, 168–175, doi:10.1016/j.pepi.2017.07.010.

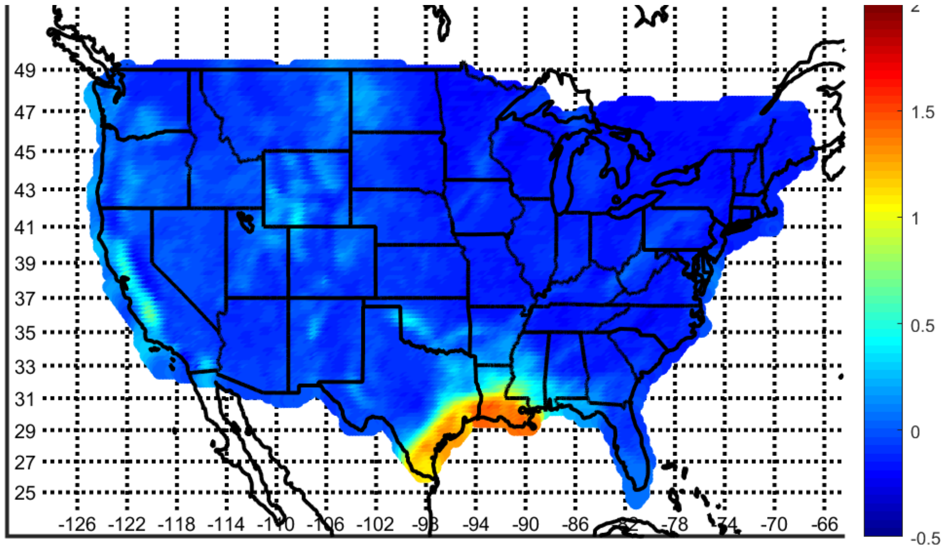

Fig. 2. P wave vertical travel time perturbation ΔT_P

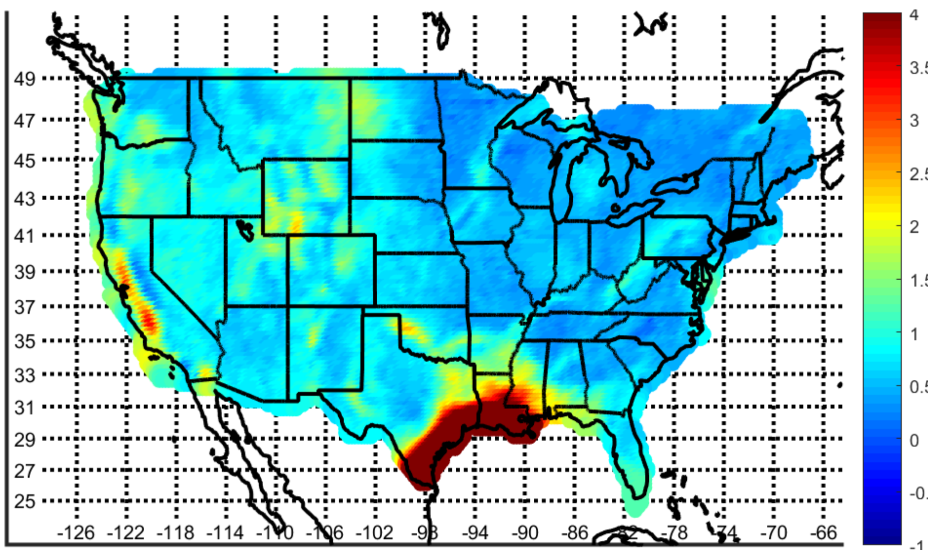

Fig. 3. S wave vertical travel time perturbation ΔT_S