Correcting Telesesimic P and S Travel Times for Moho Depth Variations

Bill Menke, 9/16/2019

We develop formulas for estimating teleseismic P and S wave travel times T_P and T_S, respectively, for Moho depth, using the map by Schmandt et al. (2015). We use a simple Earth model with an upper crust, a lower crust, uppermost (sub-Moho) mantle and upper-mantle (Figure 1A). The upper crust has fixed thickness $H_1 = 8$ km, compressional velocity $v_{p1} = 5.6\,\text{km/s}$ and compressional-to-shear velocity ratio $v_{P1}/v_{S1} = 1.78$. The lower crust has variable thickness $H_2 = h$ and fixed $v_{P2} = 6.8$ km/s and $v_{P2}/v_{S2} = 1.78$. The uppermost mantle has $v_{P3} = 8.0$ km/s and $v_{P3}/v_{S3} = 1.8$ and extends to at least 60 km depth. Below 60 km depth, v_P and v_S increase with depth, reaching $v_P = 8.3$ km/s and $v_S = 1.83 v_P$ at the depth of 210 km. The thickness of the lower crust varies according to $h = D - H_1$, where D is crustal thickness. We trace a P or S wave with an angle of incidence of 30° at 210 km depth (typical of telesesimic waves that turn in the lower mantle) to the earth's surface and compute the travel times T_P and T_S from a reference depth of 60 km to the surface. Travel times anomalies ΔT_P and ΔT_S are calculated for a reference thickness of $D_{ref} = 38$ km. Best fit lines provide a formula for $\Delta T_P(D)$ and $\Delta T_S(D)$ (Figure 1B).

The vertical travel times through the upper 60 km of the earth are given by:

$$T_P(D) = 7.7792 + \Delta T_P(D) \quad \text{and} \quad T_S(D) = 13.8105 + \Delta T_S(D)$$

$$\Delta T_P(D) = (-0.9358) + (0.0246)D$$

$$\Delta T_S(D) = (-1.5701) + (0.0413)D$$

These formulas, evaluated for Schmandt et al's (2015) data are shown in Figures 2 and 3.

Reference: Schmandt, B., Lin, F. C., & Karlstrom, K. E. (2015). Distinct crustal isostasy trends east and west of the Rocky Mountain Front, Geophysical Research Letters, doi.org/10.1002/2015GL066593.

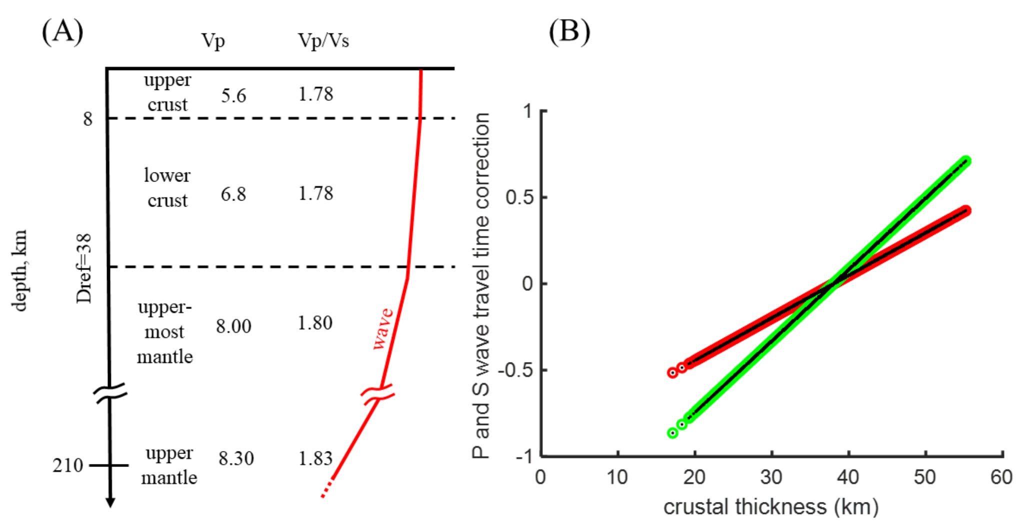

Fig. 1. (A) Earth model. (B) Calculated travel time corrections ΔT_P (red) and ΔT_S (green) and best-fit straight lines.

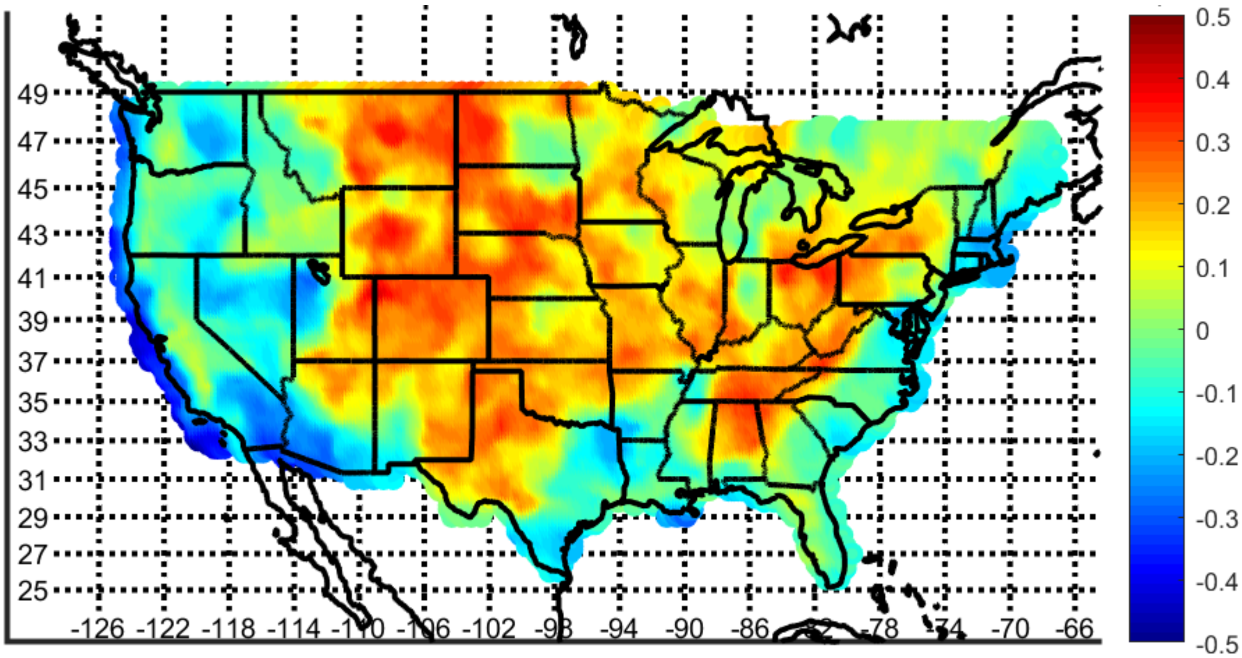

Fig. 2. P wave travel time perturbation ΔT_P.

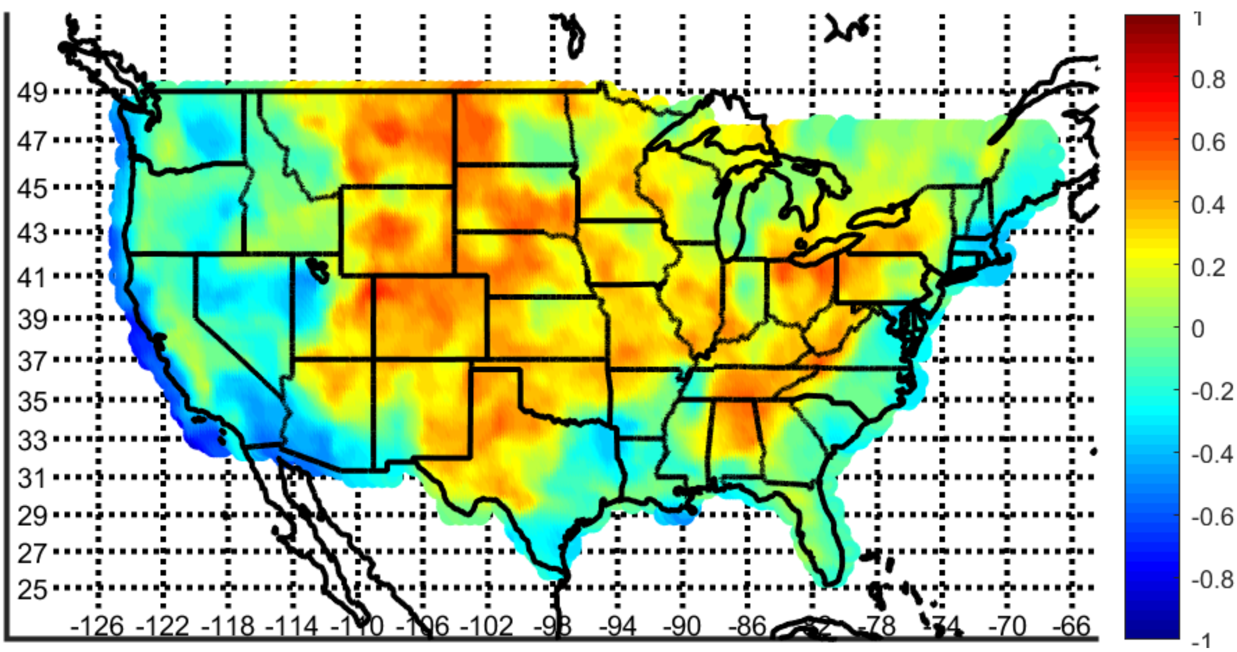

Fig. 3. S wave travel time perturbation ΔT_S.