Constraints from receiver functions and ambient noise tomography on the structure and support of the Colorado Rocky Mountains from the CREST experiment

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Abstract-

The Colorado Rocky Mountains are the most prominent topographic feature in the western US with a mean elevation of 3.2 km within a 500 by 300 km area. The timing of uplift(s) and support mechanisms of the current topography are contested, but from the sedimentary record it is clear that this region was near sea-level in the late-Cretaceous. We present preliminary seismic findings for the CREST array which consisted of 59 stations and was deployed within the Colorado Rocky Mountains for a period of 15 months from 2008–2009. The array was temporally coincident with the EarthScope Transportable Array (TA) and this data is incorporated into this study. The resulting dataset consists of data from 91 stations with a mean spacing of ~23 km. To investigate the structure of the crust and the upper mantle, receiver function and ambient noise tomography analysis is used. Rayleigh wave phase velocities are measured from the ambient noise field by correlating the continuous data recorded by station pairs and the dispersion data is inverted for a shear velocity model. For the receiver functions, teleseismic P waveforms are deconvolved and migrated to depth using our 3-D surface wave velocity model. Two crustal thickness maps are presented as estimated by each analysis: the Moho arrival is picked from the common conversion receiver function stack, and the maximum vertical shear wave velocity gradient from the dispersion inversion is picked. The crustal thickness maps are generally consistent and show ~8 km of variation across the region. The topography of the Colorado Rockies is poorly correlated with crustal thickness; most of the highest topography is associated with relatively thin crust (~40 km), similar to the adjacent Colorado Plateau and High Plains, while northern Colorado and the San Luis Valley have the thickest (~45 km) crust. The regions of thinner crust in the central Rockies are also associated with a lower mean shear wave velocity for the crust.

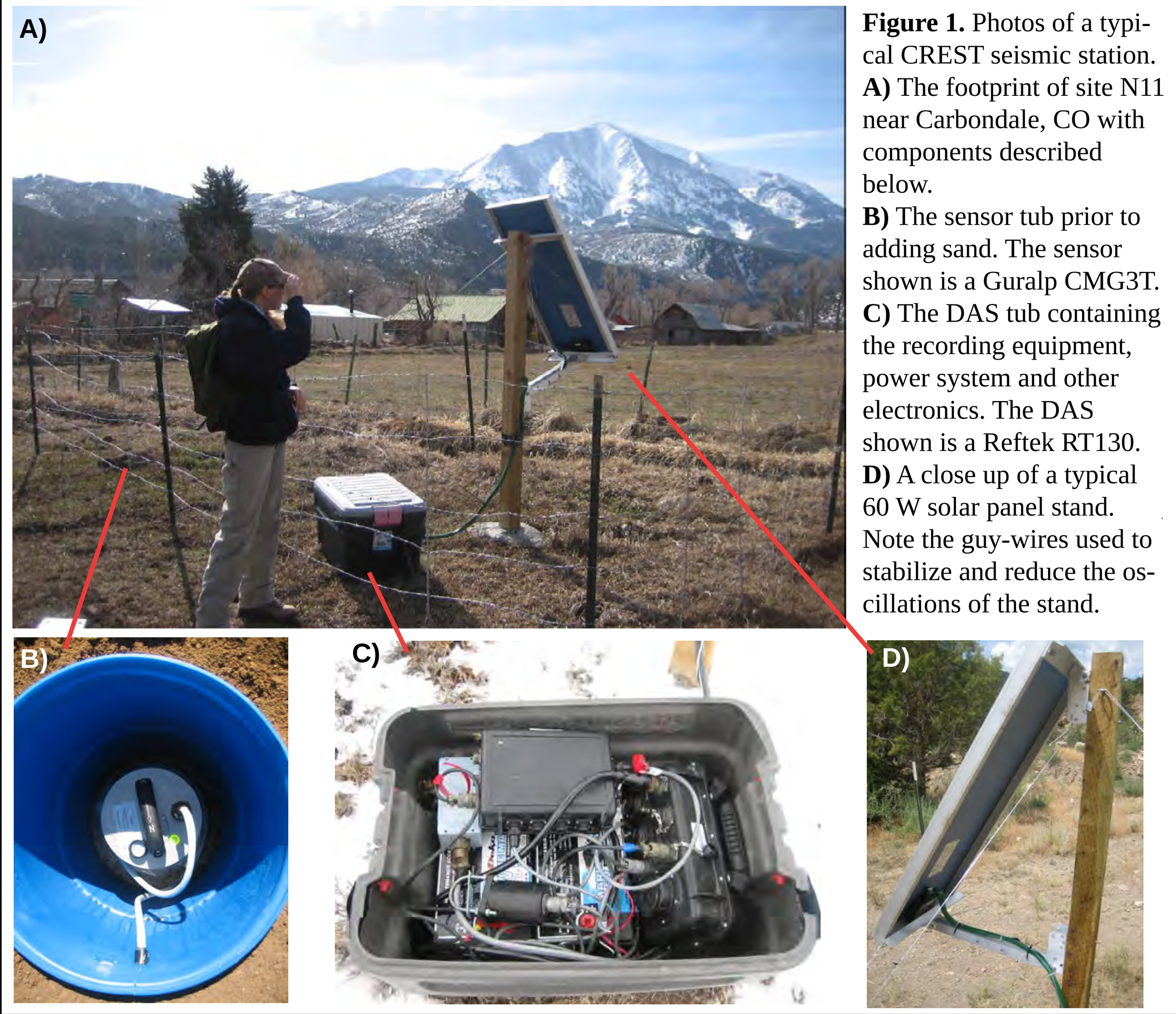


Figure 1. Photos of a typical CREST seismic station. **A)** The footprint of site N11 near Carbondale, CO with components described below. **B)** The sensor tub prior to adding sand. The sensor shown is a Guralp CMG3T. **C)** The DAS tub containing the recording equipment, power system and other electronics. The DAS shown is a Reftek RT130. **D)** A close up of a typical 60 W solar panel stand. Note the guy-wires used to stabilize and reduce the oscillations of the stand.

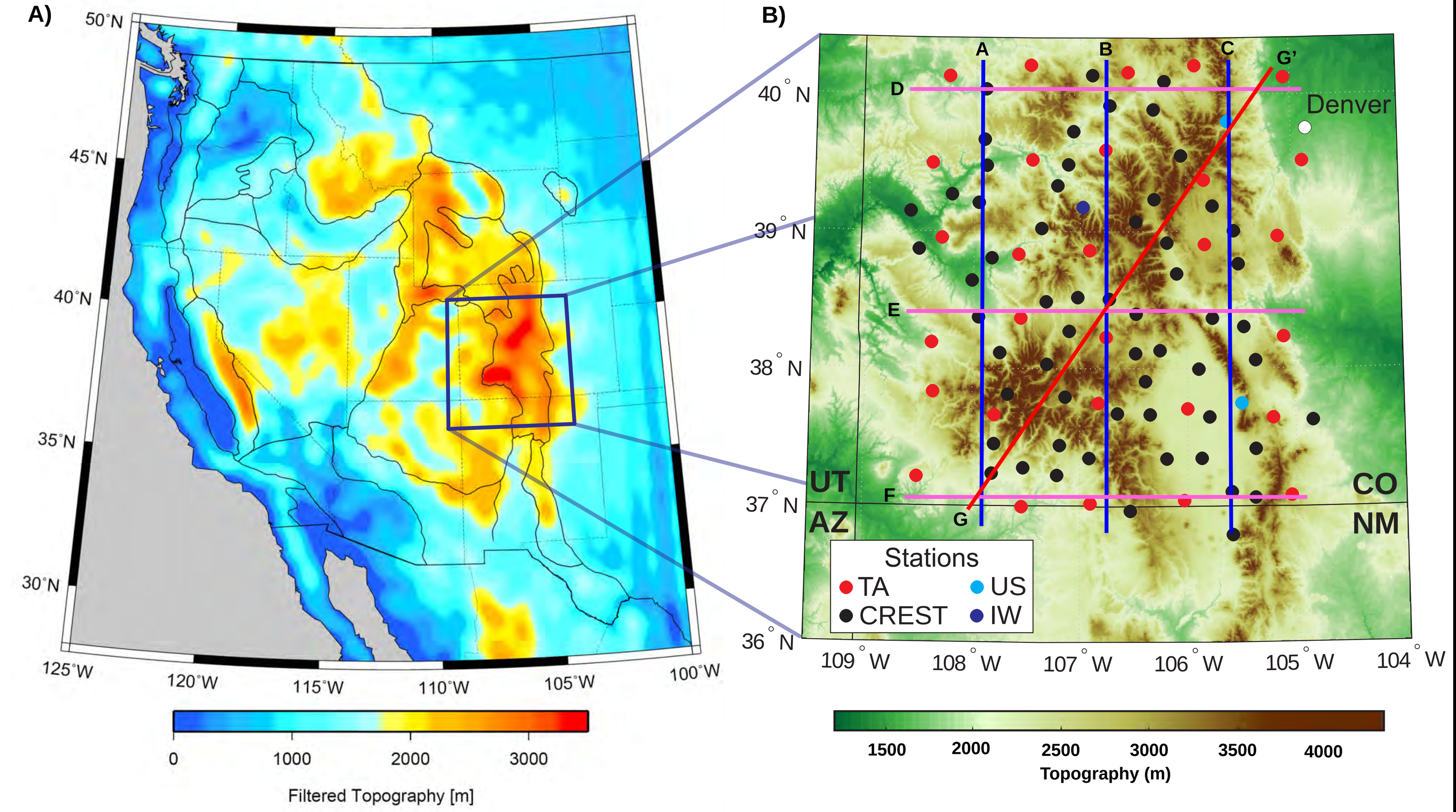
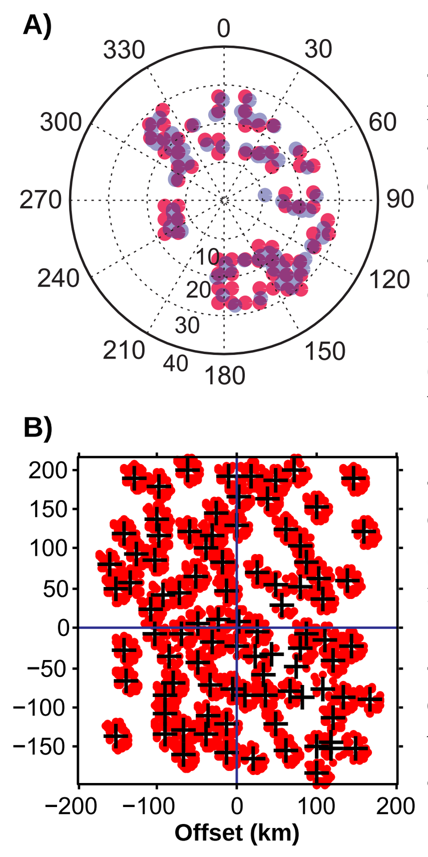


Figure 2. Regional topography and CREST array footprint. **A)** Filtered topographic map of the Western United States. The location of this experiment is outlined in blue. **B)** Blown up topographic map of western Colorado showing the Colorado Rockies and the locations of the seismic stations used in this study (circles). Cross sections from the receiver function CCP stack shown in Figure 4 are denoted by colored lines and lettered.

Receiver function data



- A total of 93 broadband seismometers which recorded for ~18 months are used in this dataset

- Includes the 59 station CREST array, 31 stations from the Transportable Array (TA) and 3 stations from the US network.

- After processing and data culling there are a total of 3185 receiver functions (RF) from 207 events

- RF are mapped from time to depth via CCP stacking using the ambient noise Vs model and a Vp/Vs of 1.75.

Figure 3. Event distribution used in receiver function processing. **A)** Polar plot showing the back-azimuth and theoretical incidence angle of the direct P wave events recorded by the array (blue circles) and the event bins used for simultaneous deconvolution (red circles). **B)** Pds ray piercing points at 60 km depth. Station locations are denoted by black crosses and individual piercing points are red circles.

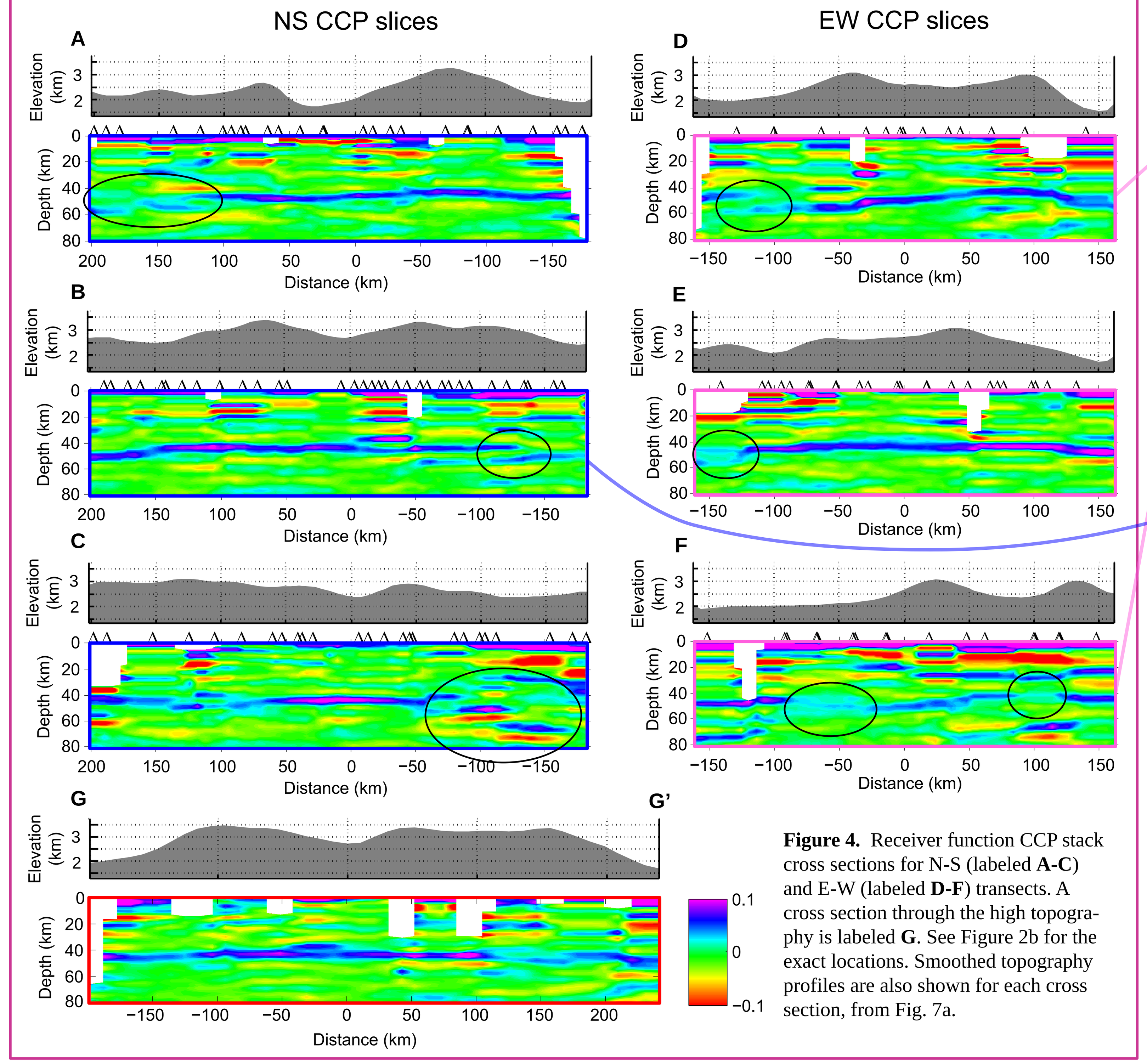


Figure 4. Receiver function CCP stack cross sections for N-S (labeled **A-C**) and E-W (labeled **D-F**) transects. A cross section through the high topography is labeled **G**. See Figure 2b for the exact locations. Smoothed topography profiles are also shown for each cross section, from Fig. 7a.

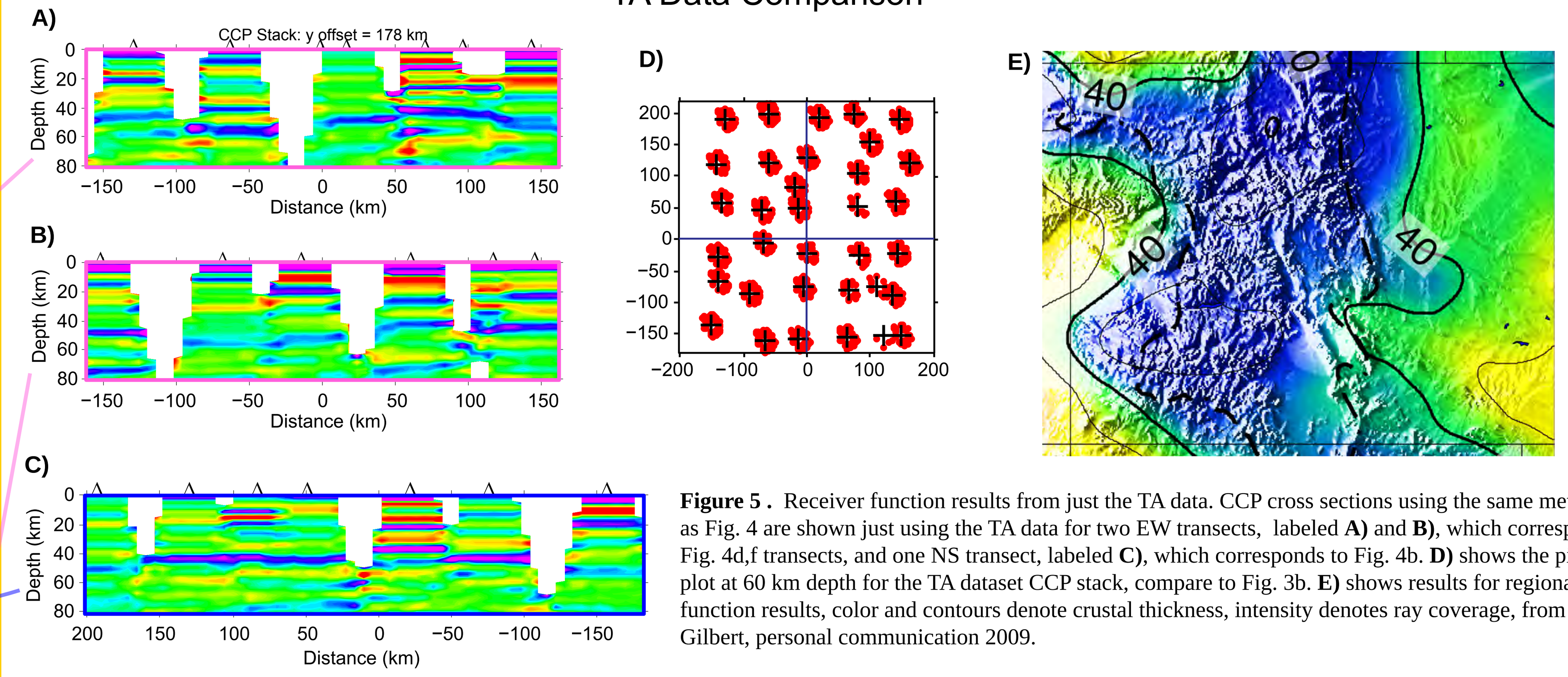


Figure 5 . Receiver function results from just the TA data. CCP cross sections using the same methodology as Fig. 4 are shown just using the TA data for two EW transects, labeled **A)** and **B)**, which correspond with Fig. 4d,f transects, and one NS transect, labeled **C)**, which corresponds to Fig. 4b. **D)** shows the piercing plot at 60 km depth for the TA dataset CCP stack, compare to Fig. 3b. **E)** shows results for regional receiver function results, color and contours denote crustal thickness, intensity denotes ray coverage, from Hersh Gilbert, personal communication 2009.

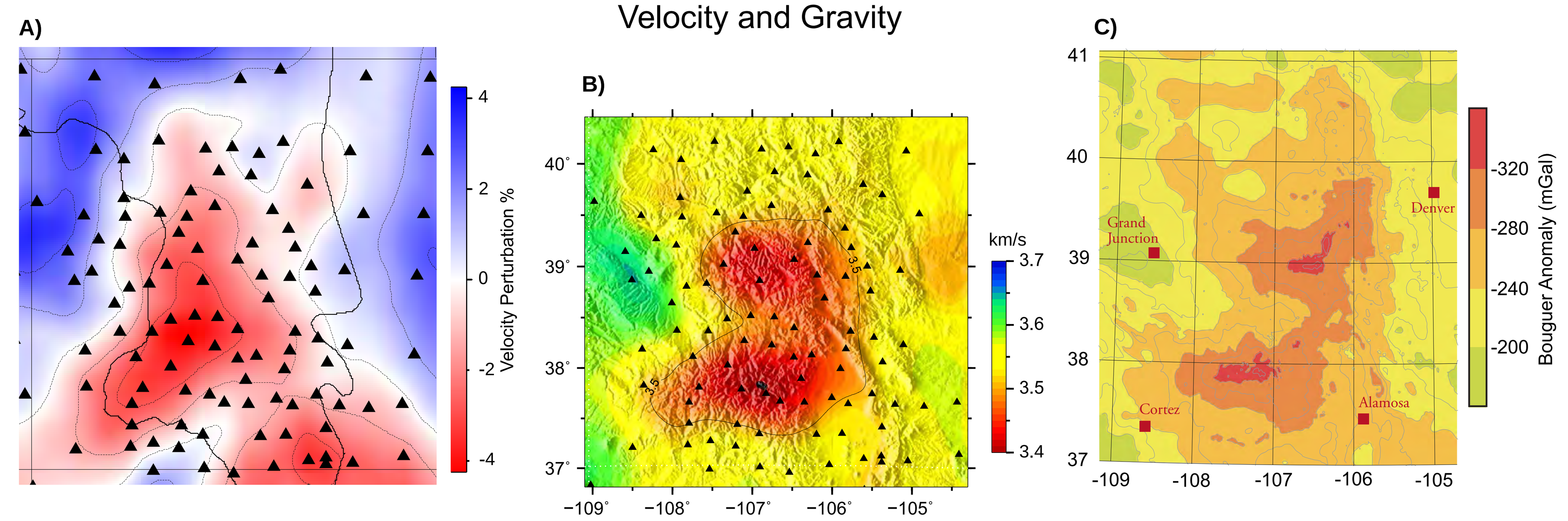
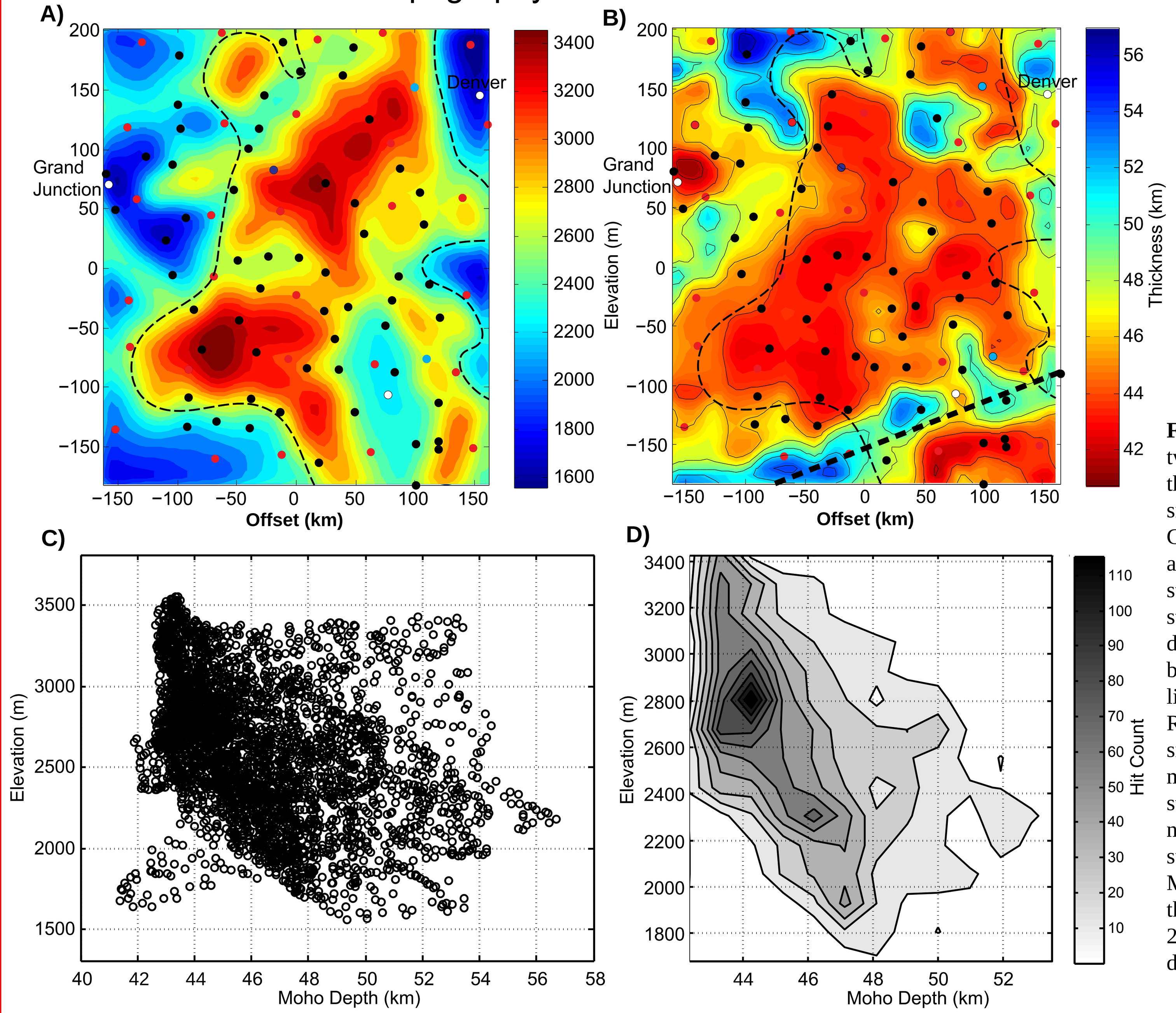


Figure 6 . Velocity and gravity data for the Colorado Rockies. **A)** S wave tomography model at 125 km depth from CREST and TA data, **see MacCarthy et al. poster**. **B)** shows the mean crustal shear wave velocity from ambient noise tomography. **C)** Bouguer gravity anomaly map for the Colorado Rockies. Modified from Reiter (2007), *GSA bulletin*. Contour interval is 20 mGal.



- elevation and crustal thickness are anti-correlated

- correlation coefficient: **-0.37**

Figure 7. Relationship between topography and crustal thickness. **A)** shows the smoothed topography for the CREST array, CREST stations are shown by black dots, TA stations by red dots and US stations are shown by blue dots. Major cities are denoted by white dots. Thin dashed lines outline the Colorado Rockies. **B)** shows the smoothed crustal thickness map derived from the CCP stack. Thick dashed line denotes a possible proterozoic suture. **C)** is a scatter plot of Moho depth vs elevation for the data in A) and B). **D)** is a 2-D histogram of the scatter data in C).

Major Findings-

- Crustal thickness ranges from 57-41 km beneath the Colorado Rockies.

- Topography and crustal thickness are anti-correlated with a correlation coefficient of **-0.37**

- The high topography of the Colorado Rockies is not supported via Airy isostasy and crustal thickness variations cannot explain the observed Bouger gravity anomaly.

- Thickened crust is possibly associated with Proterozoic structures in northern and southern CO

- From tomography results, the high topography is correlated with low shear wave velocity in the upper mantle and a lower mean crustal velocity

Future Work-

- Include ballistic surface wave dispersion measurements for better depth resolution in the tomography model.

- Construct a crustal Vp/Vs model by applying the HK stacking methodology to the RF data.

- Integrate the P wave tomography and gravity data to investigate the possible effects of mantle buoyancy on topography.

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Aster, R., ,McCarthy, J., Karlstrom, K.E., Coblentz, D., Ouimet, W., Kirby, E., Van Wijk, J., Schmandt, B., Kelley, S., Lazear, G., Crossey, L. J., Crow, R., , Aslan, A, Darling, A. and the rest of the CREST working group.

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