Study of the Moho Depth and Crustal V_p/V_s Variation in Southern California from Teleseismic Waveforms

2001 Annual Project Summary

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1 Investigation undertaken

In the year 2001, 42 new broadband digital stations were added to the southern California TriNet network, bringing the total number of stations to 162 by the end of September 1. We selected 425 teleseismic earthquakes of magnitude larger than 5.5 between September 2000 and September 2001 and retrieved all available three-component P waveforms from the TriNet data center. Each seismogram was visually examined and low signal/noise ratio traces were discarded. We have obtained more than 21,000 three-component waveform records. The number of records for the last year alone is more than the total number of waveform records obtained for the previous 7 years!

The data are processed according to the proposed research plan. We first align all vertical records from the same event on the P onset using a multi-channel cross-correlation technique. A graphics user interface program were written to allow us to chose correlation window and adjust the alignment interactively. This greatly reduces the time to process all waveform records. After the alignment, all vertical components of waveforms from the same event are stacked to produce the effective source time function (STF) for this earthquake. The STF represents the waveform shape before it interacts with crustal structure under each station. We then compute receiver function for each station by removing the source time function from the original waveforms. This was done using a time domain deconvolution algorithm using the Wiener filtering theory. The deconvolution results were visually checked and bad traces were discarded. From the 21,000 new P waveforms, we obtained 3,200 receiver functions. The total number of receiver functions for the whole 8 years (1993 to 2001) is 14,883.

We then stack receiver functions of each station using different crustal thickness (H) and V_p/V_s ratio (κ) to estimate the "optimal" Moho depth and crustal V_p/V_s ratio under the station. We improved the H-κ stacking by separating it into two steps. We first only stack the primary converted phases for different H while fixing κ. The location of the maximum stacking amplitude gives the "optimal" crustal thickness for this κ. This thickness is converted back to time delay of the Moho P-to-S converted wave Ps. We find that this

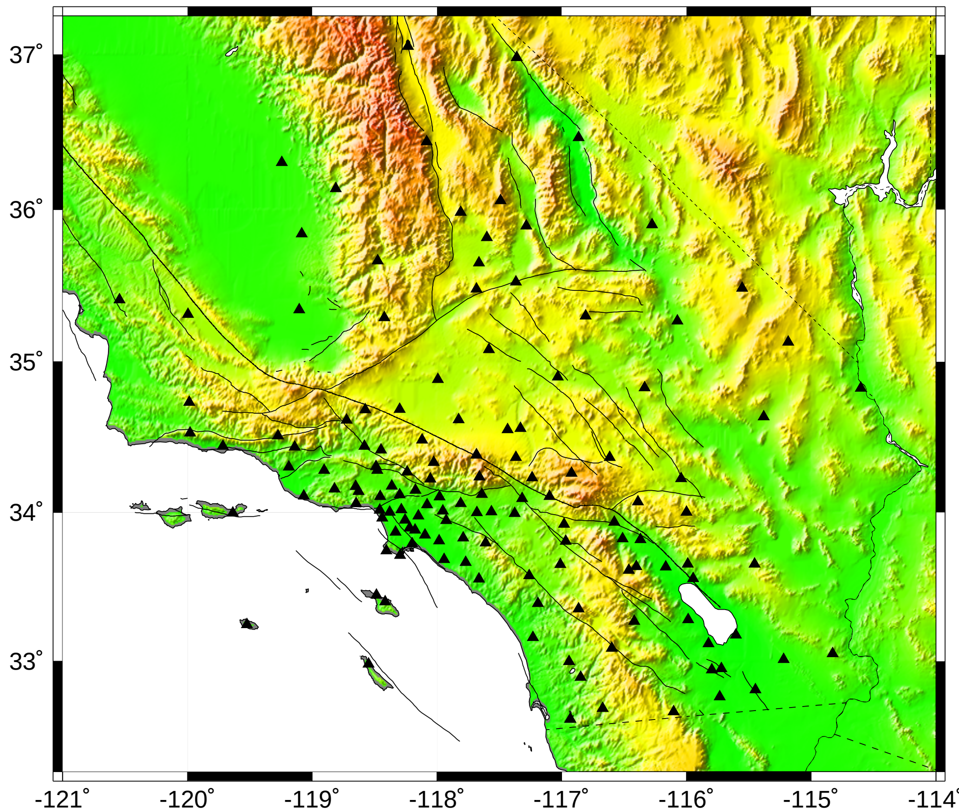

Figure 1: Distribution of broadband seismic stations of the TriNet network in 2001.

is a robust estimate of the time delay of the Moho Ps and it is essentially not dependent on the assumed κ ratio. The next step is to stack multiple converted phases ($PpPs$ and $PsPs + PpSs$) for different κ while requiring that H gives the measured Ps delay. The maximum of this κ-stacking gives the "optimal" crustal V_p/V_s. Fig. 2 shows an example of the stackings for station PAS.

2 Results

We processed all receiver functions of 162 stations and obtained the delays of the Moho Ps for 154 stations. Fig. 3 shows variation of delays in different locations. These delays are also converted into crustal thickness assuming a crustal V_p/V_s ratio of 1.8 and a P velocity of 6.3 km/s. We found that under the Peninsular Ranges, the eastern Transverse Ranges, and the west of Sierra Nevada Ranges, the delays are large and therefore the crust is thick. In contrast, the delays are small for stations located in the Salton trough and offshore California Borderland. This indicates thin crust in these areas. The stations in the Mojave Desert have the average delay.

We also obtained 41,657 high quality P arrival times from the cross-correlation procedure. We calculated station delays of teleseismic travel time by averaging delays of all events for each station. They are shown in Fig. 4. Large delays for station located in the LA basin

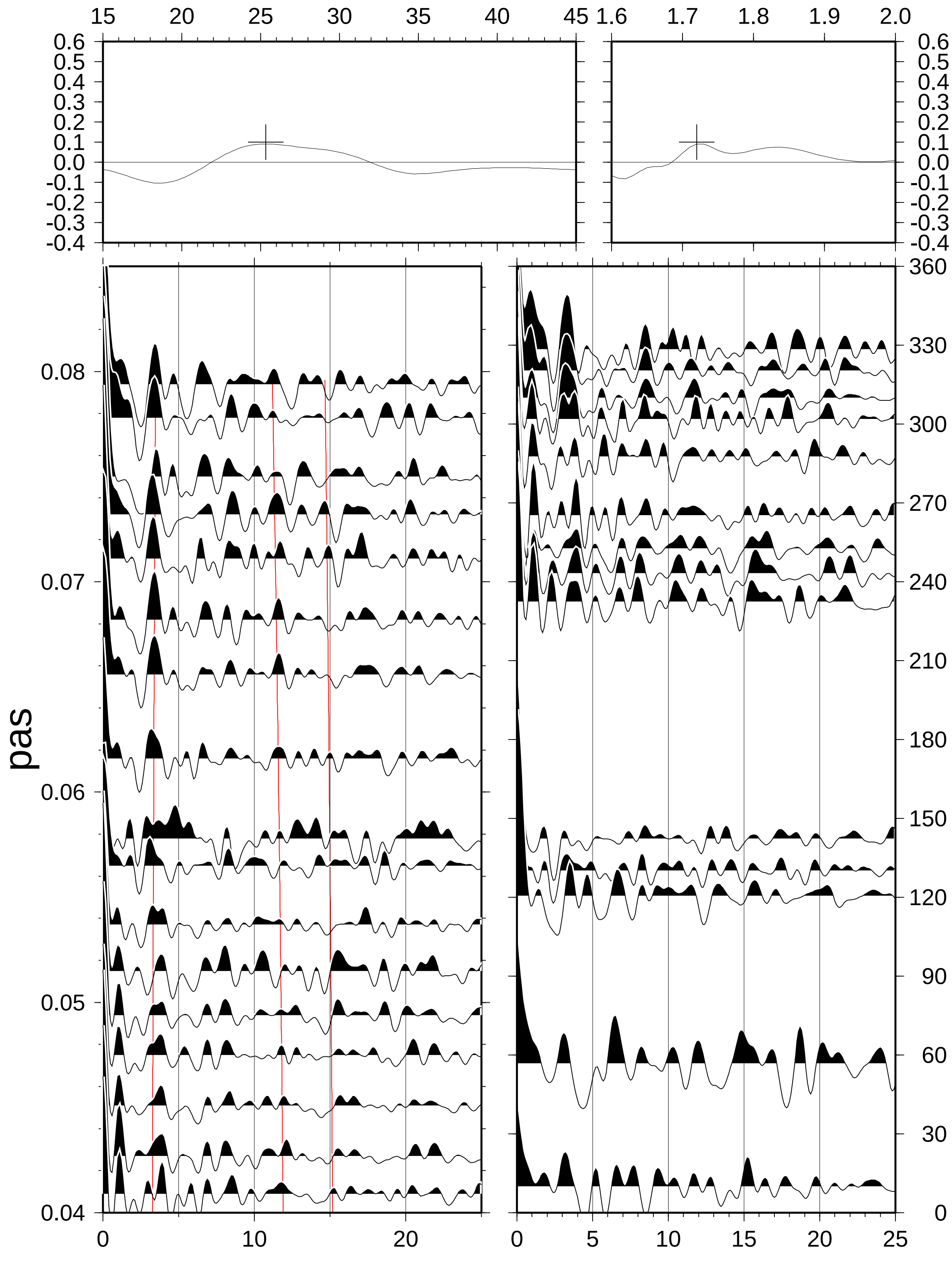

Figure 2: H and κ stackings of PAS receiver functions. Upper-left is stacking for different crustal thickness (in km) while fixing $\kappa = 1.8$. Upper-right is stacking for different crustal V_p/V_s ratio κ. The bottom shows receiver functions for different ray-parameters (left) and back-azimuths (right).

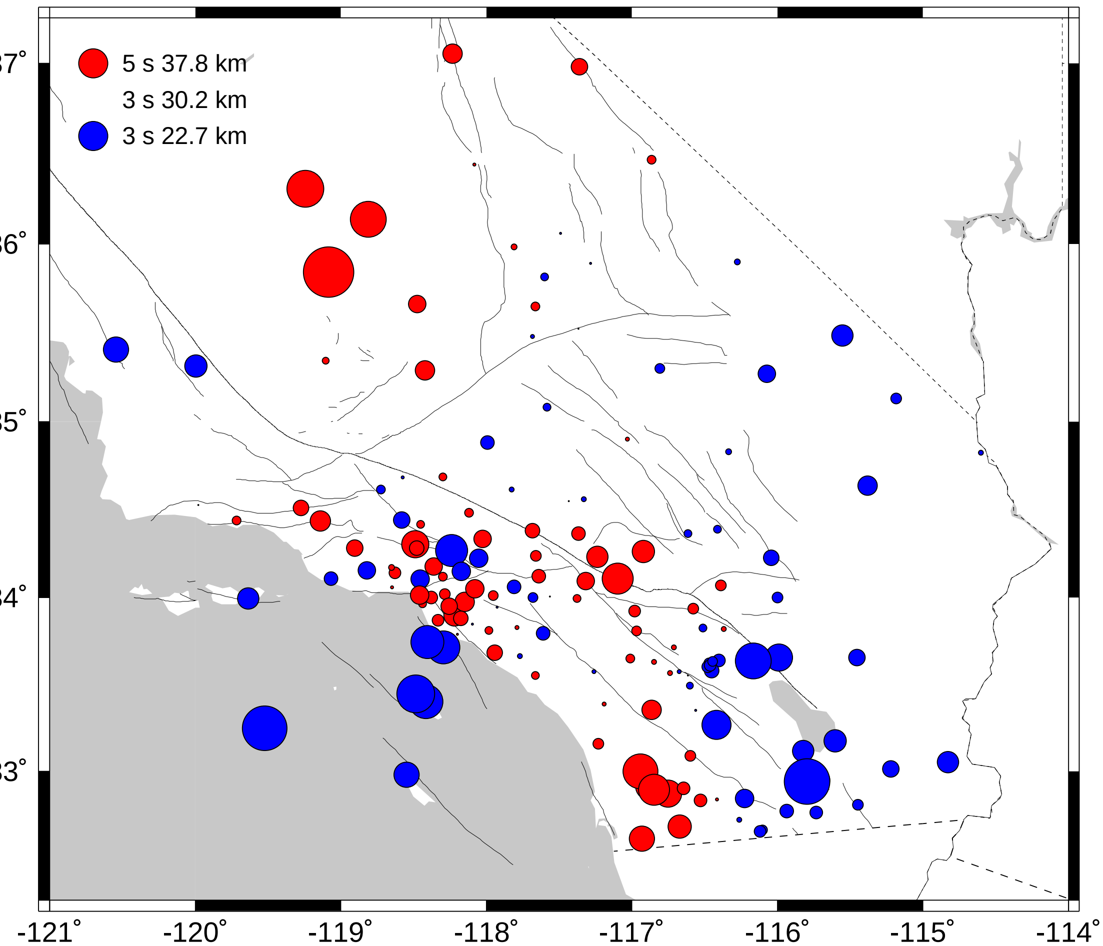

Figure 3: Variation of delays of Moho Ps. They are measured at a teleseismic ray parameter of 0.06 s/km. The scale is shown at the top-left corner. These delays are also converted into crustal thicknesses assuming a crustal V_p/V_s ratio of 1.8 and a P velocity of 6.3 km/s.

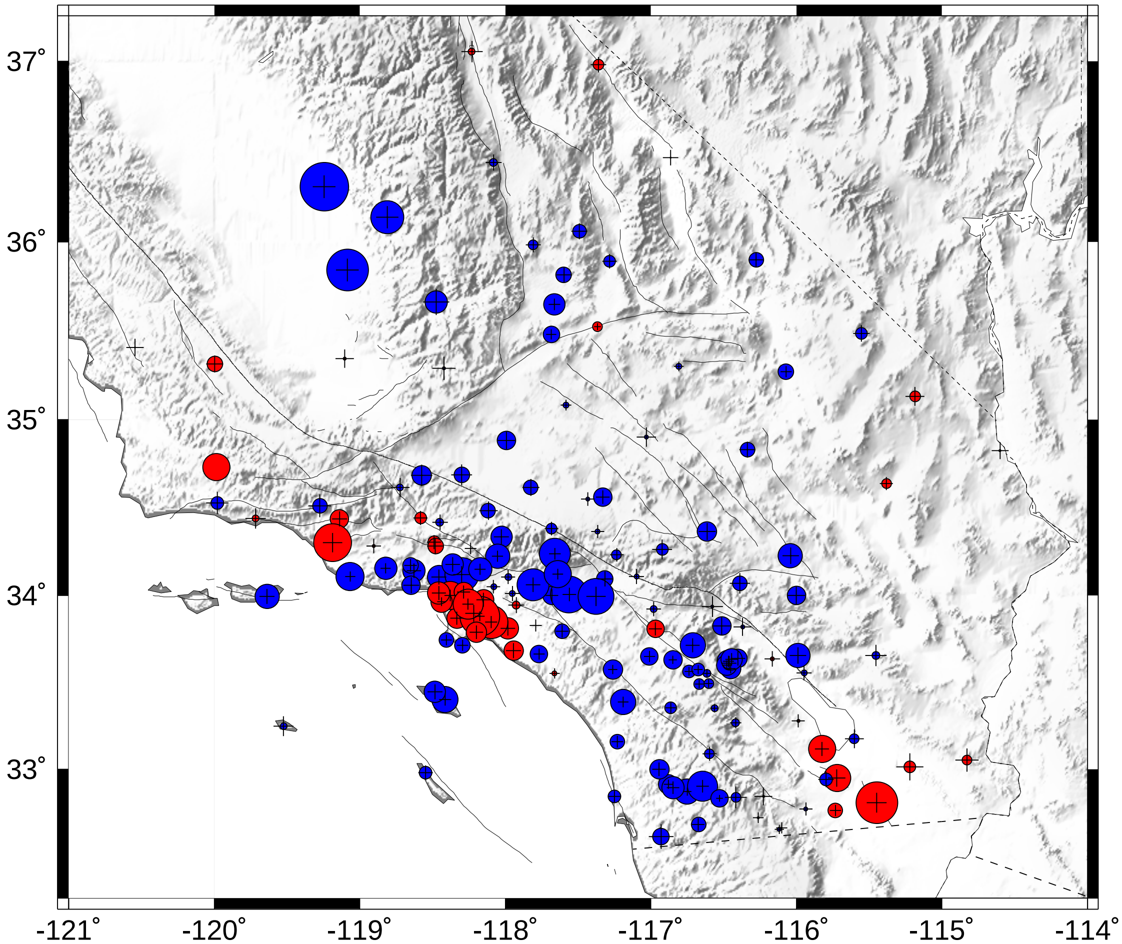

Figure 4: Station delays of teleseismic P travel time (red means positive delays). The elevation differences are corrected assuming a P velocity of 5 km/s at the top of the crust.

and Salton trough are likely to be caused by thick sediments in those areas. We can also see two areas that have negative station delays: under the Transverse Ranges and west of Sierra Nevada. These are places where high mantle velocity anomalies were reported.

3 Non-technical summary

More than 21,000 teleseismic earthquake waveform records from 165 global earthquakes were retrieved from the TriNet data center and were processed. In total, we obtained 14,883 teleseismic receiver functions for 160 broadband seismic stations in southern California. From these receiver functions, we estimated crustal thickness and V_p/V_s ratio under each station. The results show that the average crustal thickness in southern California is about 30 km. Places such as the Peninsular Ranges, the eastern Transverse Ranges, and the west of Sierra Nevada Ranges have thicker crust, while regions of the Salton trough and offshore California Borderland have thinner crust.

4 Reports published

Zhu, L. and L. A. Riveral, 2001, A note on the dynamic and static displacements from a point source in multi-layered media. GJI (in press).

Ben-Zion, Y. and L. Zhu, 2001, Potency-magnitude Scaling Relations for Southern California Earthquakes with $1.0 < M_L < 7.0$, GJI (in press).

Zhu, L., 2001, Preliminary Results of Crustal Structure from the LARSE-II Passive Recording Experiment Using Teleseismic P-to-S Converted Waves (abstract), 36th Annual Meeting of GSA Cordilleran Section, May 2001, Universal City, CA.

Zhu, L., 2001, High Resolution Imaging of Crustal Structure Across The San Andreas Fault (abstract), SEG Summer Workshop, July 2001, Newport Beach, CA.

Zhu, L., 2001, Summary of Results of Crustal Structures Using Teleseismic Waveforms from LARSE (abstract), SCEC Annual Meeting, September 2001, Oxnard, CA.

Zhu, L. 2001, Summary of Results of Crustal Structures Using Teleseismic Waveforms from LARSE (abstract), AGU 2001 Fall meeting, San Francisco, CA.

5 Data availability

The estimated crustal thicknesses and V_p/V_s ratios of 71 broadband stations in southern California are available via anonymous ftp to earth.gps.caltech.edu. The results are in plain text format named as /pub/lupei/jgr2000.tbl. The Moho depth on a uniform grid of 0.1 degree spacing is also available in the GMT 2D grid format at the same location (/pub/lupei/jgr2000Moho.grd). For detailed information, contact Lupei Zhu (email: lupei@eas.slu.edu, Tel: 314 977-3118).

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