16th World Conference on Earthquake Engineering, 16WCEE 2017

Santiago Chile, January 9th to 13th 2017

Paper N° 1680

Registration Code: S-XXXXXXXX

ONE DIMENSIONAL CRUSTAL STRUCTURE OF ISPARTA REGION FROM BROADBAND MODELLING

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Abstract

Modeling broadband waveforms from small local and regional earthquakes is useful for determining source parameters and to infer details of crustal and upper mantle structure [1]. This paper aims to model crustal structure of Isparta region from broadband data.

The Isparta Region, situated in the intersection of Hellenic and Cyprus arcs related to the collision of the African and Anatolian plates, possesses a complex structure. To further understand this complexity, three-component broadband waveforms of a M_w=5.1 magnitude event recorded on the Suhut (SHUT), Konya (KONB) broadband, high dynamic range instruments, were modeled to examine the effects of perturbations of the crustal model on the synthetic seismograms using a frequency wave-number integration code. This code makes it possible to synthesize three-component seismograms that are complete in that there are no ray truncations, and they include surface waves and near- and intermediate field terms. The result of the sensitivity analysis, final crustal velocity model and final source parameters obtained are discussed herein.

Keywords: Broadband Modeling; Crustal Structure; Isparta Region; Southwestern Turkey

1. Introduction

The focus of this study is the Isparta Region (southwest Turkey), located at the boundary between the West Anatolian Extensional Province (WAEP) and the relatively stable Anatolian Plateau (Fig. 1). The Isparta Region possesses a complex structure and the main structural feature in this region is the Isparta Angle, situated at the intersection of the Hellenic and Cyprus arcs[2, 3]. Isparta Angle, N- to S- trending right lateral suture zone, was formed by the clockwise rotation of the western side and counter-clockwise rotation of the eastern side during the Neotectonic period [3].

An event with Magnitude M_w = 5.1 occurred in the Isparta Region on April 10, 2007, at a depth of approximately 14km, as reported in the ANSS (Advanced National Seismic System) Catalog. Fig. 2 shows the location of earthquake epicenter (represented by the circle), which was located at Egirdir Lake (latitude 37.96° N, longitude 30.87° E), and the location of the three seismic stations (represented by triangles) called SHUT (Suhut), KONB (Konya) and, GLHS (Golhisar) stations. These stations consist of three-component broadband, high-dynamic range instruments.

This paper aims to model crustal structure of Isparta Region from broadband data recorded at these stations. It reveals that a large quantity of information about earthquakes sources and propagation effects can be understood using a limited amount of data from the broadband waveform data recorded at a few stations. Once the crustal structure is modeled, this knowledge may be useful to study the sources of sparsely recorded historic earthquakes and estimate ground motion for other credible events in this region.

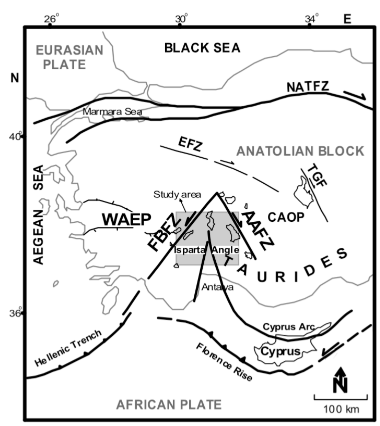

Fig. 1 – Simplified tectonic map of West Turkey. Abbreviations: NATFZ, North Anatolian Transformation Fault Zone; FBFZ, Fethiye-Burdur Fault Zone; AAFZ, Afyon-Aksehir Fault Zone; EFZ, Eskisehir Fault Zone; WAEP; West Anatolian Extensional Province; CAOP, Central Anatolian Ova Province (from Dolmaz, 2007)

Fig. 2- Location map (epicenter represented by the circle, and the locations of the three seismic stations represented by triangles)

2. Methodology

An event with Magnitude $M_w = 5.1$ occurred in the Isparta Region on April 10, 2007, at a depth of approximately 14km, as reported in the ANSS catalog. The reported strike/dip/rake (slip angle) for the two possible fault planes 25/50/-58 and 161/50/-122. Fig. 3 shows the vertical component records, which were recorded on 3 different broadband stations (SHUT, KONB, and GLHS stations). The data was instrument corrected and integrated to displacement. SHUT is located 68km away from the epicenter at an azimuth of 332 degrees, while the KONB and GLHS stations are located 126 km and 157 km away from the epicenter with 92.8 degrees and 233 degrees azimuth, respectively.

This paper illustrates forward modeling of the records to improve the velocity models in along the path to station KONB. A frequency wave-number integration (FKI) code written by Chandan Saikia was used. This code synthesizes three-component seismograms that are complete in that are complete in terms of body and surface wave arrivals as well as for the near-, intermediate- and far-field terms. FKI code assumes 1D plane layered structure and accounts for attenuating media.

Assuming the event is a well-located point source and the reported focal mechanism, the wave propagation effects are analyzed in the seismograms to model the crustal structure. Sensitivity analyses are conducted to assess the important of various components of the derived velocity models. Once the final crustal structure is obtained, this knowledge may be used to study the sources of sparsely recorded historic earthquakes and possibly to estimate ground motions for other credible events in this region. Future work will test this model against the two other stations mentioned previously, and the paths to those stations will be adjusted as needed.

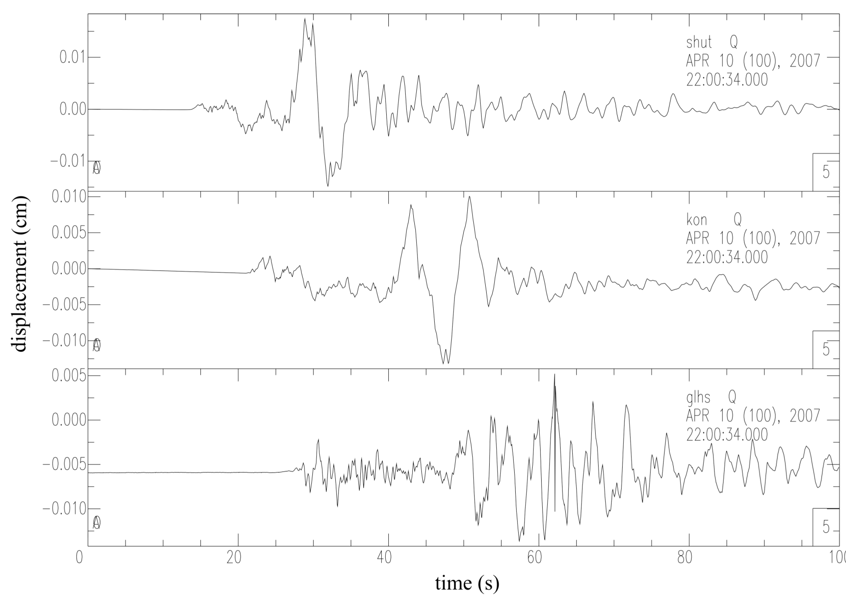

Fig. 3- Vertical components of the 10 April 2007(M_w=5.1) earthquake recorded at SHUT, KONB and GLHS broadband stations.

3. Sensitivity Analyses and Crustal Velocity Modeling

Since both source and propagation parameters are needed in computing synthetics seismograms, the source parameters must be constrained by other seismic measurement or assumptions to be able to study crustal structure. Therefore, the source parameters determined from the Global Centroid Moment Tensor (GCMT) database were considered fixed in our analysis. Given the constrained source parameters, the velocity model was perturbed until good agreement with the data was obtained.

Fig. 4 compares vertical component of synthetic seismograms with recorded data for KONB station. The left side of the figure represents broadband raw (recorded data) and synthetics for different models while the right side of the figure shows the data in the 0.02 to 0.1Hz passband. An acausal 4-pole Butterworth filter was applied. The initial velocity model (modsoc) with a source at 14 km depth is used to obtain the inital synthetics (Refer to Table 1). The starting velocity model (modsoc) is a slightly modifed version of the Socal model which is approproate for paths in Southern California [4]. Forward modeling was then performed by reducing the upper layer shear wave velocity by 60% ("redsrc Velocity Model" in Table 1) to model the Rayleigh wave. The reduction in velocity is in accordance to some models for the region from the literature [5, 6, 7, 8]. In the modeling we assumed a Poisson ratio of 0.25 to estimate V_p from the Vs modeling until better V_p model is obtained by fitting the P-waves.It may be easily observed that this significant reduction in upper layer shear velocity was too much (refer Fig. 4) and it was decided to increase upper layer velocities by 16% (redsrc2) and another 12% (redsrc3). The density was kept constant.

Table 1 - One dimensional velocity models used

Initial Model (inimod)			
Vp (km/s)	**Vs (km/s)**	**r (g/cc)**	**Z (km)**
5.5	3.2	2.2	0
5.9	3.4	2.7	5.5
6.7	3.9	2.8	16
7.8	4.5	3.3	35

2nd Model (redsrc)			
Vp (km/s)	**Vs (km/s)**	**r (g/cc)**	**Z (km)**
3.4	2.0	2.2	0
5.9	3.4	2.7	5.5
6.7	3.9	2.8	16
7.8	4.5	3.3	35

4th Model (redsrc3)			
Vp (km/s)	**Vs (km/s)**	**r (g/cc)**	**Z (km)**
4.5	2.6	2.2	0
5.9	3.4	2.7	5.5
6.7	3.9	2.8	16
7.8	4.5	3.3	35

5th Model (redsrc4)			
Vp (km/s)	**Vs (km/s)**	**r (g/cc)**	**Z (km)**
4.5	2.6	2.2	0
6.2	3.6	2.7	5.5
6.7	3.9	2.8	16
7.8	4.5	3.3	35

It is also important to realize the fitting of early P waves while trying to fit surface wave since a constant ratio is used between S and P wave velocity. As part of velocity sensitivity analyses, the source layer velocities were also increased by 5 % (redsrc4) to observe the effects of source layer velocity change in the synthetics. Velocity sensitivity analyses were conducted mainly by comparing the broadband and band pass 0.02 to 0.1 Hz vertical component synthetics with data recorded at KONB station.

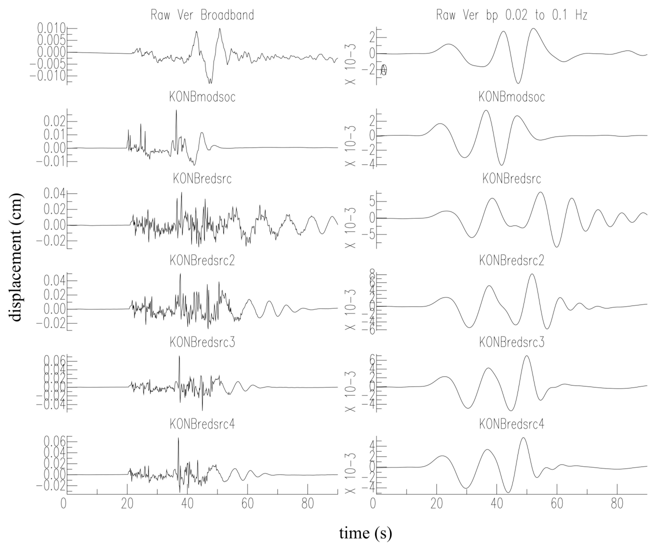

Fig. 4 – Comparison of vertical component synthetic seismograms with observed (the first row of the figure) data recorded at KONB station.

Layer thickness sensitivity was analyzed using the redsrc4 velocity model as a starting velocity model, where each layer thickness was perturbed to observe the effects on the vertical component synthetics. It was found that by increasing the source layer thickness between source and the midcrustal discontinuity below (the Conrad Discontinuity) that an improvement in fit was achieved. Fig. 5 represents broadband and bandpass filtered KONB vertical component synthetics for 2km(redsrc4), 7km, 12km and 17km thickness of source layer below the source. The increasing layer thickness is effectively deepening both the midcrust and Moho discontinuities in the model. The improvement in the amplitude was observed in the broadband seismograms (observed raw data at the first row of the Fig. 5) as the depth increased. Although model with 17km thickness had a better fit of the amplitude, the model with 12 km led to better fit compared to the other models since it captured the shape of the first arriving P waves in the broadband record, and the surface waves in the bandpass filtered records.

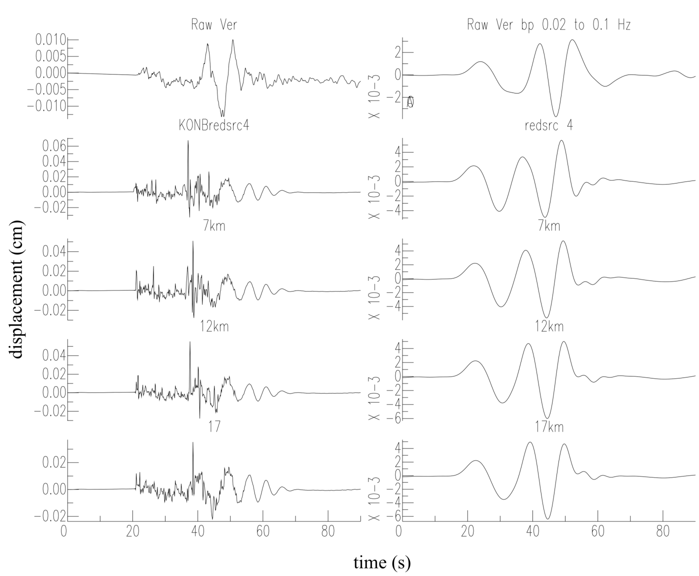

Fig. 5 - Results of the thickness sensitivity analysis (The observed KONB data is shown in the first row).

To better model the unfiltered data different source time histories were tested. Using different trapezoidal and exponential source time functions we found that a trapezoidal time function with a 0.75 sec rise time, 0.5 sec duration, 0.75 sec fall time improved the fit to the data (Fig. 6).

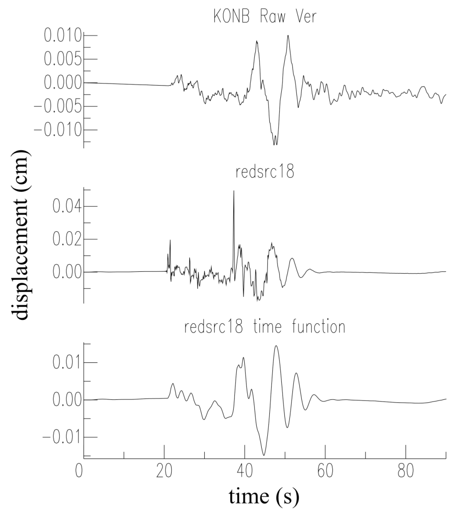

Fig. 6 - Comparison of vertical component synthetic with observed (first row of the figure) data before and after convolution

As observed in Fig. 6, the final velocity model after the source time function is convoled leads to 3 successive P wave peaks, while the raw data has only 2 P waves peak. The sensitivity of upper layer thickness was analysed and convolved the same trapezoidal time function with synthetics obtained for different thickness between 3.5 km and 7.5 km. Although, the upper layer thickness improves the P waves slightly, it significantly disturbed S waves fit. Models without a Conrad or Moho discontinuities were tested to see if the third P wave arrival was a phase associated with those discontinuities and it was found that it was not indicating that it is a consequence of the structure above the source. Thus the final crustal velocity model resulting in the fit to the data shown in Fig. 6 is given in Table 2**.**

Table 2 – Final 1D Crustal Velocity Model

Final Model(r8t or redsrc8t)			
Vp (km/s)	**Vs (km/s)**	**r (g/cc)**	**Z (km)**
5.0	2.9	2.1	0
6.2	3.6	2.5	5
6.6	3.9	2.8	26
7.3	4.3	3.1	45

Fig. 7 and Fig. 8 represent the comparisons of vertical component KONB data and SHUT data with synthetic seismograms. It is seen that the model performs well at modeling the vertical component records at both KONB and SHUT. The final model also provides a good fit to the radial component and reasonable fit to the tangential component considering it is nodal at this azimuth (Fig. 9).

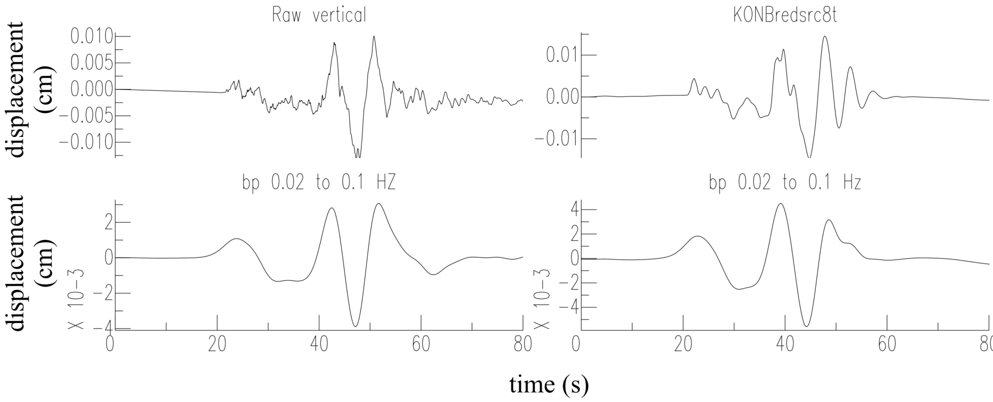

Fig. 7 – Comparison of vertical component of synthetic seismograms (on the right) obtained with final velocity model to observed data (on the left) for KONB station

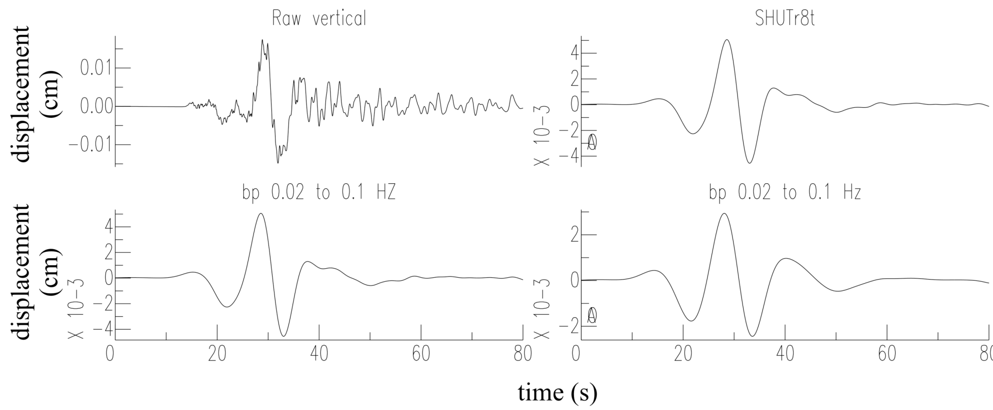

Fig. 8 – Comparison of vertical component of synthetic seismograms (on the right) obtained with final velocity model to observed data (on the left) for SHUT station

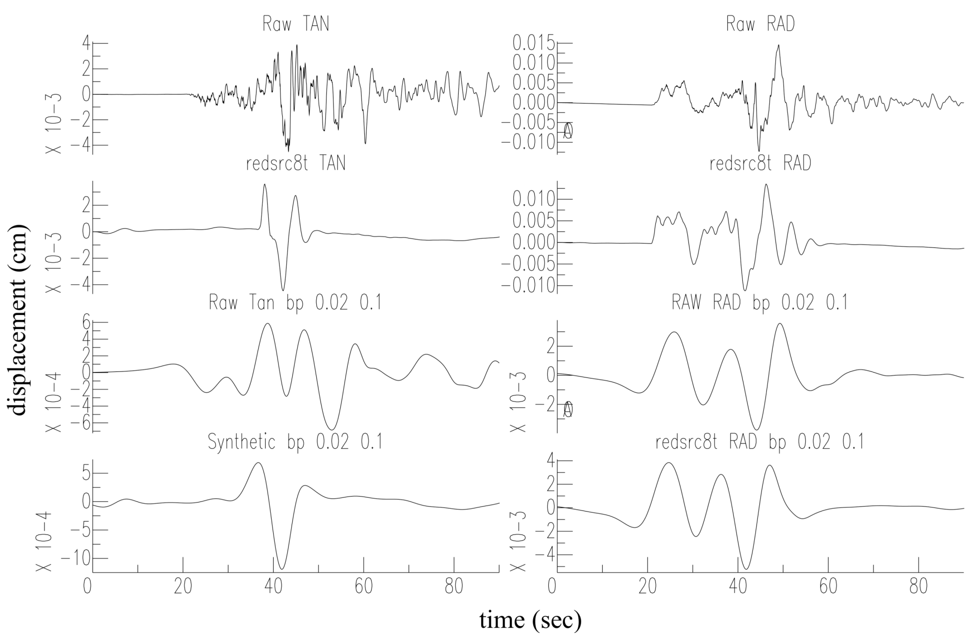

Fig. 9 - Comparison of tangential component synthetics (left column) to observed data (first row) and comparison of radial components synthetics (right column) to observed data (first row) at KONB station

4. Conclusion

Modeling broadband waveforms from small local and regional events shows great promise in determining source parameters and inferring details of crustal and upper mantle structure in the Isparta Region of Turkey. Although, lateral heterogeneity in velocity structure is one of the principal obstacles to overcome, it is possible to interpret broadband records with relatively simple 1D model without knowing the fine structural details. A velocity model (Table 2) was found forIsparta Region, along the paths to Egirdir-Konya (KONB) and Egirdir-Suhut (SHUT). The usefulness of this crustal structure model may be envisioned in several ways such as studying historic events and in simulations of large events from a given source region.

5. References

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