VELOCITY STRUCTURE OF TURKEY AND SURROUNDINGS BY PASSIVE IMAGING TECHNIQUE

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ABSTRACT:

Ambient seismic noise records are used to determine the group velocity variations in Turkey and surrounding regions. High resolution velocity structure of Turkey and surroundings were obtained by using Passive Imaging Technique. A waveform database for ambient seismic noise correlation was constructed from more than 450 temporary and permanent broadband stations. Cross correlations of the ambient seismic noise are calculated to determine surface wave Green's function for all station pairs in the region. The high number of stations and the amount of data provides sufficient numbers of Greens functions. Determination of the high resolution group velocity maps by using Passive Imaging Technique provides the finer details of the crustal and upper mantle structure. Together with the estimation of crustal structure the technique will also be used for the investigation of deep basins. The results of this study will help to improve tectonic models proposed for Turkey and surrounding areas.

KEY WORDS : Ambient seismic noise, Surface wave, Tomography, Crustal structure, Turkey

1. INTRODUCTION

Turkey and the surrounding areas has been the target of many geophysical studies due to its active tectonics and the high seismicity rate. Continuous regional deformation along the seismically active boundaries contains diverse structures such as suture zones, metamorphic core complexes and young orogens (Stampfli, 2000). Significant variations exist on the tectonic styles and crustal structures. Various continental blocks that make up present-day tectonics of Turkey is mainly divided into six major lithospheric fragments (Figure 1) including the Strandja, the Istanbul and the Sakarya zones, the Antolide-Tauride Block, the Kırşehir Massif and the Arabian Platform (Şengör and Yılmaz, 1981; Okay, 1989; Okay *et al.*, 1994). In most of the investigations on the crustal thickness and seismic velocities sparse distribution of seismic stations were used in the region (Mindevalli and Mitchell, 1989; Maggi and Priestly, 2005). Love wave group velocity maps were obtained as a whole for Turkey and surrounding areas by Cambaz and Karabulut (2010) with dense path coverage.

A new research area of seismology is the investigation of Earth by using ambient seismic noise rather than earthquakes or artificial sources. Recent laboratory and theoretical studies have shown that the Green's function between two stations can be obtained from the cross-correlation of ambient seismic noise. After the 17 August 1999 İzmit earthquake high amount of broadband stations were installed in Turkey mainly by KOERI and AFAD. Ambient seismic noise records are used for imaging the structure of the crust and uppermost mantle with increased resolution by using a dense station distribution. A database for noise correlations was constructed from the continuous recordings of approximately 450 permanent and temporary broadband stations during 2006-2010. The cross correlations of the ambient seismic noise are calculated to determine surface wave Green's function from each station pairs in the region.

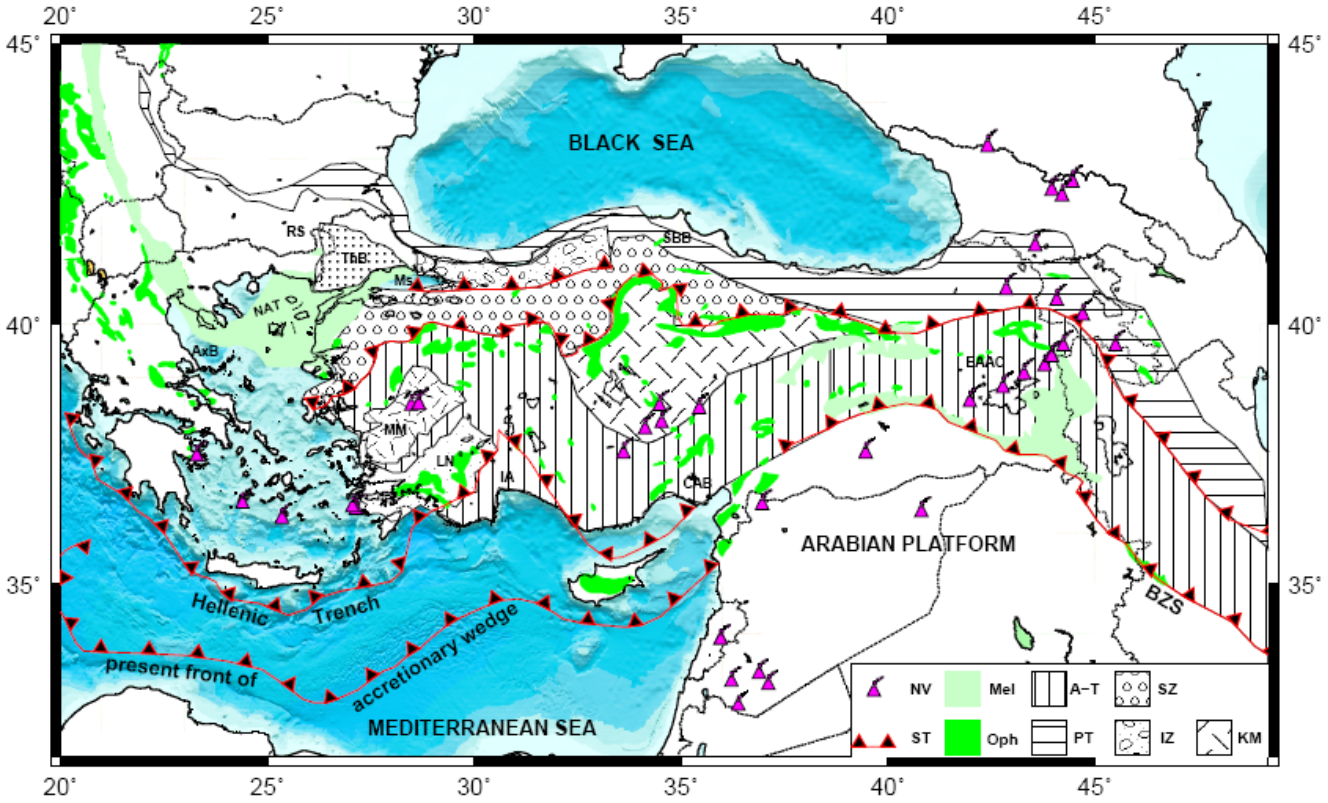

Figure 1. Tectonic setting of Turkey; AxB, Axios Basin; A-T, Anatolid-Tauride Block; CAB, Clicia-Adana Basin; EAAC, East Anatolian Accretionary Complex; IA, Isparta Angle; IZ, Istanbul Zone; KM, Kırşehir Massif; LN, Lycian Nappes; MM, Menderes Massif; NAT, North Aegean Trough; PT, Pontides; RS, Rhodope-Strandja Basin; SBB, Sinop-Boyabat Basin; SZ, Sakarya Zone; ThB, Thrace Basin. Green and light green units represent the ophiolites and ophiolitic mélanges, respectively. Bathymetry of the region derived from ETOPO5. Purple volcano signs show neogene and quaternary volcanism. Red triangles show the sutures and earlier subduction zones (Cambaz and Karabulut 2010, modified from Okay and Tüysüz 1999; Robertson 2000; Tatar *et al*., 2000; Yılmaz *et al*., 1998; Stampfli, http://www-sst.unil.ch/research/plate_tecto/present_day.htm).

1.1. Data

In the investigation of passive imaging technique temporary broadband stations of KOERI and AFAD and permanent broadband stations of ETSE, WASRE, NAF and SIMBAAD projects have been used. Supplementary data from IRIS and ORFEUS depository were obtained for the permanent stations operated in the region by various networks such as MEDNET, GEOFON, IRIS, AUTH, NOA, and the seismic networks of Romania, Bulgaria and Hungary. Figure 2 shows the locations of the seismic stations operating in the region by different networks, which is used in this study.

1.2. Computation of Green's Function

Data processing procedure applied in this study is similar to the one described in the work of Bensen *et al*., (2007). Data from all the stations in the region are sampled to one sample per second prior to data processing. Then 24 hour long data segments are created for each station from the continuous data recordings of broadband seismic stations. Mean, trend, and instrument response are removed after the preparation of data. Earthquakes and other disturbing effects such as instrumental irregularities are removed by applying temporal normalization. Additionally, spectral whitening was applied in order to remove the effects of microseism at double frequency (~7 sec) and single frequency (~14 sec) periods. Cross-correlations and stacking are performed daily in the frequency domain.

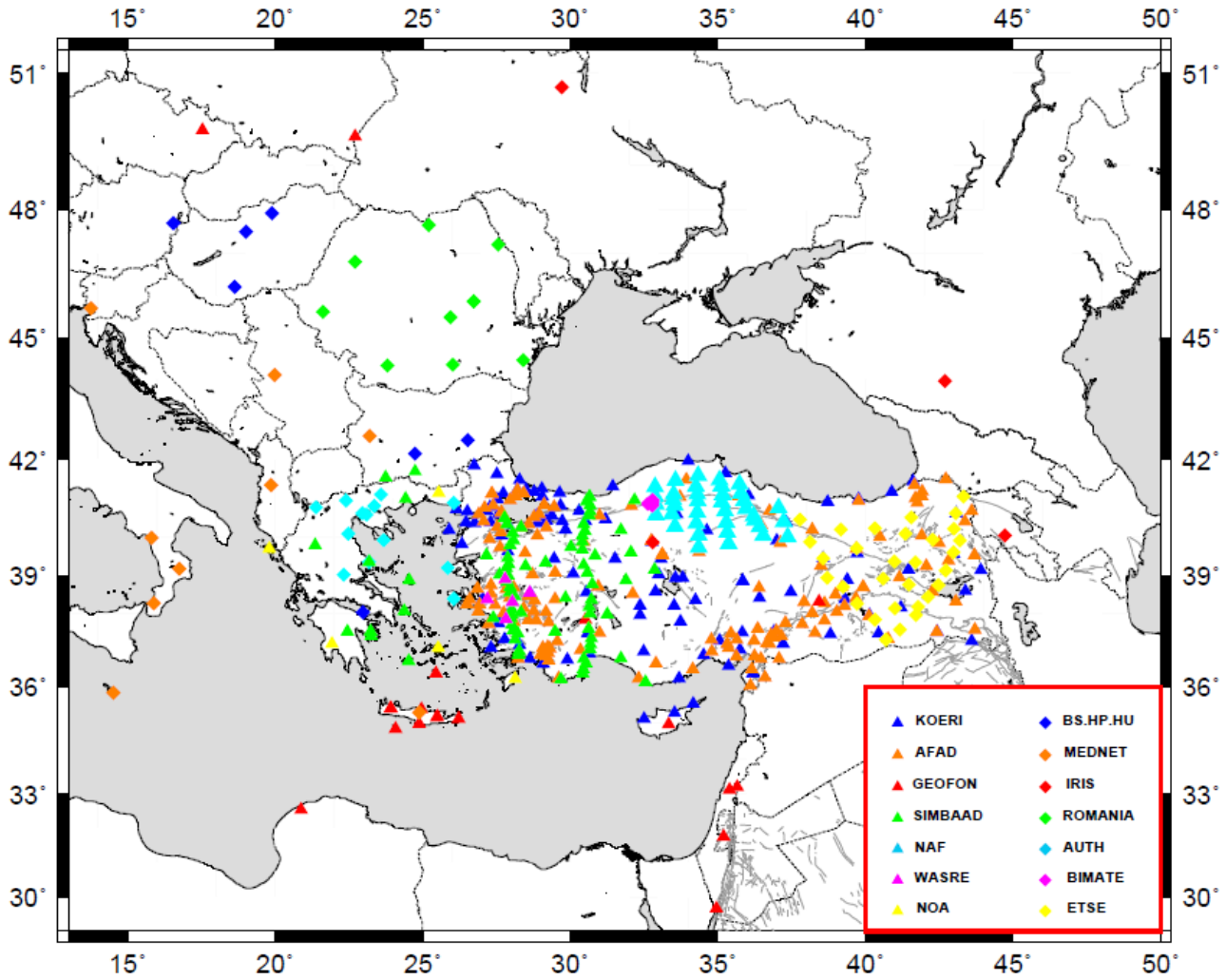

Figure 2. Station distribution from permanent and temporary networks used for ambient seismic noise correlation. Different colors indicates broadband seismic stations operated by different networks in Turkey and surroundings.

For accurate representation of Green's function a medium of homogenous and random distribution of noise sources is needed. However the noise distribution inside the earth is neither homogenous nor random. But the distribution of noise sources can be homogenized when long time sequences are used. It was introduced previously during the theoretical background of the technique that in a multiply scattering medium the convergence of cross-correlations to the Green's functions is also effective together with a sufficient number of averaging processes (Campillo, 2006). Hence, after this single station process completed, cross-correlations are computed and stacked for each station pairs by using approximately three years of data. This correlation process amounts to a number of $n(n-1)/2$ station pairs where n is the number of stations. Almost 100000 time-series were obtained from the cross-correlations of more than 450 broadband stations. Approximately 750 time series obtained from the cross correlations of ETSE stations and other broadband stations operated during 1999-2001. Two months stacks of cross-correlations of each station pair are computed and compared in order to see if there are any seasonal variations of the estimated Green's functions. The resulting cross-correlations are two-sided time-functions with both positive and negative correlation lags. In this study the correlations lags are stored from -1000 to 1000 sec which depend on the speed of the waves and the maximum inter-station distance.

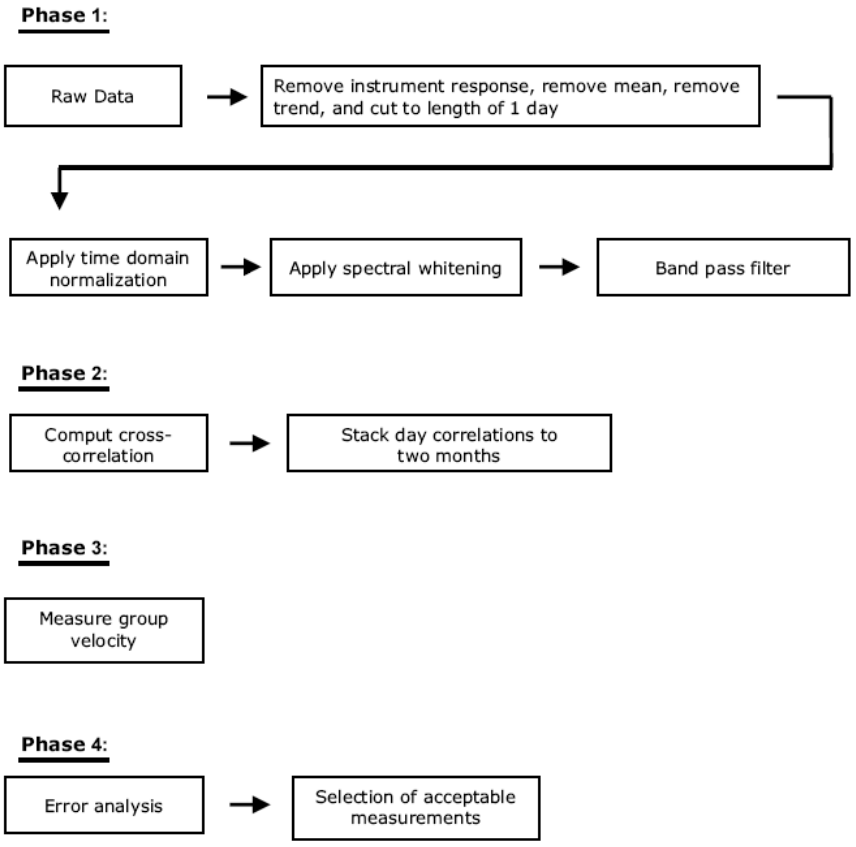

Figure 3. Schematic representation of the data process (Modified after Bensen et al., 2007).

Figure 4 shows the cross-correlations between ISP and KOZT stations. The distance between two stations is 511 km and the group wave velocity computed from both positive and negative lag is 3.2 km/s. Each trace shows the two months stacks of correlations. The resulting waveforms represent waves traveling in opposite directions between the stations. The positive and negative correlation lags which are also referred as causal and acausal, respectively, would be identical if the sources of ambient noise are distributed homogeneously in azimuth (Bensen *et al.*, 2007). However, considerable asymmetry can also be observed.

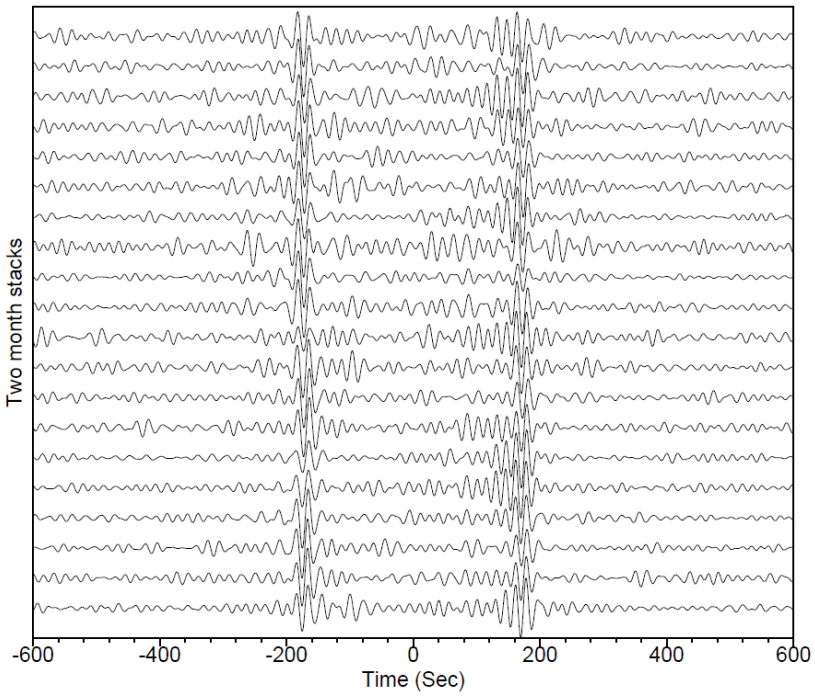

Figure 4. Cross-correlations for the vertical components of ISP and KOZT stations with inter-station distance of 511 km and filtered in the 18-22 sec period band. The traces are normalized with their maximum values.

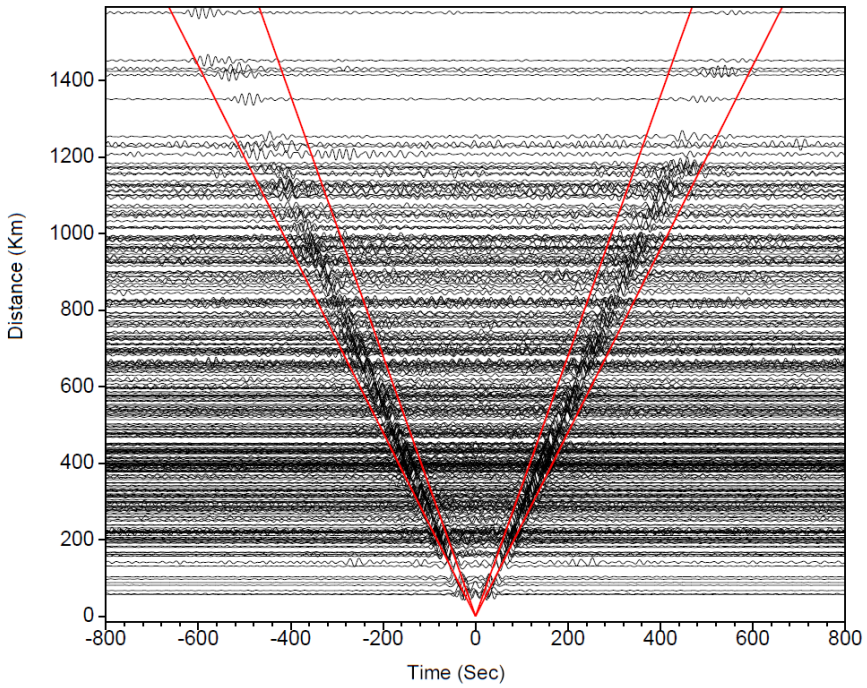

Figure 5. A record section centered at station ISP for vertical component. Cross correlations are ordered by station distances. Both positive ('causal') and negative ('acausal') lags are shown. Two sided Green's functions filtered between 18 and 22 seconds periods. Red curves indicate the minimum velocity (2.4 km/s) and the maximum velocities (3.4 km/s) at positive and negative lags.

Figure 5 shows the results of two year stacks of cross correlations between the vertical components recordings of ISP station with the other vertical components recordings of the broadband stations. The resulting waveforms correspond to the estimated Green's functions of Rayleigh waves. Cross correlations are computed at 20 sec period (18-22 sec bandwidth). In each of those cross-correlations, positive (causal) and negative (acausal) components show the Rayleigh wave signals coming from the two opposite directions. There is an obvious symmetry between positive and negative lag indicating a uniform distribution of noise. The group wave velocity envelopes 2.4 km/s and 3.4 km/s also shown on the figure indicate the expected value of Rayleigh wave velocity for 20 sec period.

3. GROUP VELOCITY MAPS

The group velocity maps were interpreted in relation to the known geological and tectonic structures in the region. The study shows the existence of significantly different crustal types in the area. Low group velocities at shorter periods (10-20 sec) are observed in local sedimentary basins, the Eastern Mediterranean and the Black Sea. The Eastern Anatolia region is also characterized by low group velocities while Pontides and Bitlis-Pötürge massif display higher group velocities. The Central Anatolia exhibits uniform velocity distribution indicating more homogenous crust. The Isparta Angle is marked by a wedge shaped-low group velocity anomaly. High velocities observed on the maps are associated with metamorphic, magmatic arcs along the orogenic belts of Pontides, Pötürge massif and crustal thinning in the Aegean region.

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