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# VALIDATION OF THE GREEN'S FUNCTIONS RETRIEVED FROM AMBIENT NOISE BY ANDIRIN EARTHQUAKE IN THE ADANA BASIN

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**Keywords**
*Ambient Noise,*
*Green's Function,*
*Surface Wave.*

**Abstract**

The vertical component continuous data recorded by the national seismological networks (Kandilli Observatory and Earthquake Research Institute (KOERI) of Bosporus University and Earthquake Research Department (ERD) of Disaster and Emergency Management Presidency of Turkey) in the Adana Basin (Southeastern Turkey) are used to retrieve the Green's functions between two stations. The noise data were cut into 1-hour segments, scanned for the gaps caused by transmission drop-outs, preprocessed by removing the trend, mean and instrument response, down sampled to 10sps and low-pass filtered at 50s. Then the hourly cross-correlations are computed and stacked and the Green's functions between two stations are retrieved. To validate the retrieved Green's functions, the Andirin earthquake of magnitude 5 occurred on 22.07.2012 near the station Andirin (ANDN) is used. By using the ANDN station as the virtual source, the Green's functions at KARA, KMRS, KIZK, MERS and YAYL stations are compared with the real earthquake seismograms. The agreement between the earthquake seismograms and the retrieved Green's functions suggests that the Rayleigh wave group velocities can reliably be estimated for the region by using ambient noise data.

# ARTALAN SİSMİK GÜRÜLTÜ VERİLERİNDEN ELDE EDİLEN GREEN FONKSİYONLARININ GEÇERLİLİĞİNİN ADANA HAVZASINDAKİ ANDIRIN DEPREMİ İLE DOĞRULANMASI

**Anahtar Kelimeler**
*Artalan Sismik Gürültü,*
*Green Fonksiyonları,*
*Yüzey Dalgası.*

**Öz**

İki istasyon arasındaki Green fonksiyonlarının elde edilmesinde Adana Havzasında (Güneydoğu Türkiye), Boğaziçi Üniversitesi, Kandilli Rasathanesi ve Deprem Araştırma Enstitüsü (KRDAE) ve Türkiye Afet ve Acil Durum Yönetimi Başkanlığı Deprem Araştırma Dairesi (DAD) tarafından işletilen ulusal sismolojik ağlarda toplanan düşey bileşen sürekli veriler kullanılmıştır. Artalan Sismik Gürültü (ASG) verileri 1'er saatlik dilimler halinde kesilip, veri aktarımındaki kopmalar nedeniyle oluşan boşluklar tarandıktan sonra, verilere trend giderme, ortalama alma, cihaz tepkisinin giderilmesi, 10 sps örnekleme ve 50s alçak geçişli süzgeç ön işlemleri uygulanmıştır. Ardından 1 saatlik çapraz ilişki fonksiyonlarının hesaplanması ve yığmaları ile iki istasyon arasındaki Green fonksiyonları elde edilmiştir. Green fonksiyonlarını doğrulamak için 22.07.2012 tarihinde Andırın (ANDN) istasyonunun yakınında meydana gelen 5.0 (Ml) büyüklüğündeki Andırın depremi kullanılmıştır. ANDN istasyonunu sanal kaynak olarak kullanarak, KARA, KMRS, KIZK, MERS ve YAYL istasyonları ile ANDN istasyonu arasında elde edilen Green fonksiyonları ile gerçek deprem sismogramları ile karşılaştırılmıştır. Deprem sismogramları ve hesaplanan Green fonksiyonları arasındaki uyum, Rayleigh dalgası grup hızlarının, ASG verilerinden bu bölge için güvenilir bir şekilde belirlenebileceğini göstermektedir.

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## 1. Introduction

As an alternative to earthquake signals, retrieving surface or body waves from background ambient seismic noise (ASN) has been a popular research topic for the last few decades. Green's functions are estimated from ASN recordings between two stations by cross-correlation and stacking. The Green's function can be described as empirical impulse response of the medium. Seismic interferometry theory allows the estimation of the Green's function between two receivers by cross-correlating the time series of seismic noise recorded at the stations to get information about the subsurface structure of the region. Previously conducted studies showed that group and/or phase velocities measured from Green's functions can successfully be used for the estimation of shear-wave velocity structure of the crust and upper mantle.

The reliability of the velocity model is dependent on how well the Green's functions can be extracted from ASN data. The objective of this study is to examine the consistency of real earthquake records and Green's functions obtained from ASN. The record of the Andirin earthquake (22.07.2012, M=5.0), which occurred at a location very close the ANDN station in the Adana Basin (Figure 1) was used as the reference. We compare seismograms recorded at KMRS, KARA, YAYL, MERS and KIZK stations with the Green's functions (obtained at these stations) for which the ANDN station was used as a virtual source (Figure 1). We observed that there is a good agreement between the earthquake seismograms and Green's functions.

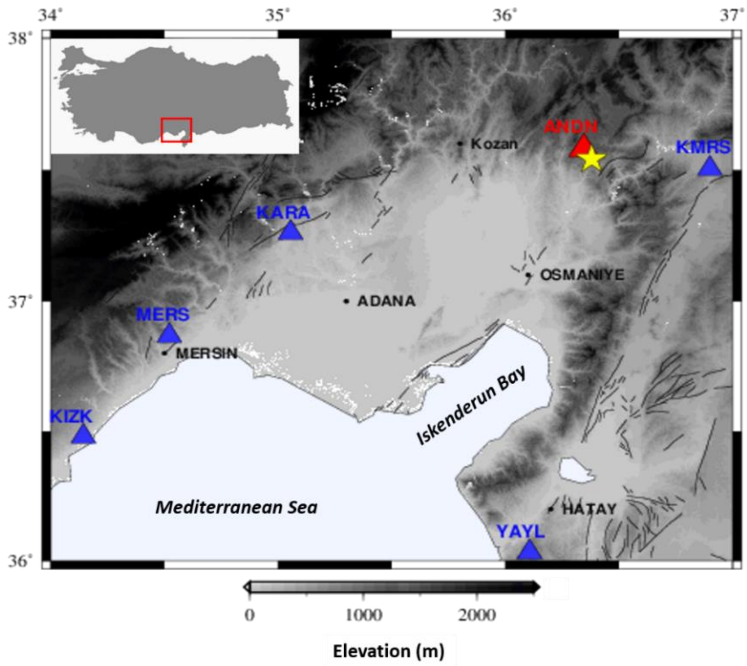


**Figure 1.** Location map of the seismic stations (triangles) and earthquake epicenter of Andirin earthquake (yellow star). Red triangle represents the reference station. Red frame represents the location of the study area in Turkey (upper left corner).

## 2. Literature Survey

Over the past few decades, ASN studies have taken an important place in crustal and upper mantle structure investigations. Numerous ASN studies have been conducted based on surface wave tomography in the global or regional scales in the world (e.g. Shapiro et al., 2005; Sabra et al., 2005; Bensen et al., 2008 and 2009, Lin et al., 2007 and 2008; Yang et al., 2010; Pawlak et al., 2011; Gao et al., 2011; Mordet et al., 2015; Asono et al., 2017; Lu and Lei 2018; Emry et al., 2019; Crowder et al., 2019; Zeng and Thurber et al., 2019).

The theoretical and experimental studies have proven that it is possible to retrieve the Green's function by cross correlating the ASN recorded at two stations (Weaver and Lobkis 2001a,b, Larose et al., 2004; Derode et al. 2003; Snieder 2004; Wapenaar 2004; Wapenaar et al. 2010a,b). With the development of the new approaches, ASN studies are used as an alternative to the traditional active source surface wave studies. Compared to utilizing the surface waves from earthquake seismograms, retrieval of Green's functions from ASN have some advantages being independent of source parameters, azimuthal distribution and similar.

The success of seismic images using ASN is related to the quality of retrieved surface waves which requires boundary sources (primary or secondary) enclosing the receivers and the stations (Wapenaar 2003, 2004; Campillo and Paul 2003; Snieder, 2004; Wapenaar and Fokkema, 2006; Schuster, 2009). Although the method, theory and practice of ASN analysis are studied by many researchers, there are a few studies including comparison of Earthquakes with the retrieved Green's functions. Shapiro and Campillo (2004), and Quattara et al. (2019) indicated significant agreement between Rayleigh waves obtained from ASN and earthquake surface wave studies. Barmin et al. (2011) used Rayleigh waves retrieved from the ASN and the earthquake seismograms in order to test the new epicentral location method. Bao et al. (2014) showed that the Green's functions from ASN records provide very similar Rayleigh wave group dispersion curves as earthquake records. Quattara et al. (2019), obtained well correlation between Rayleigh waves estimated from the earthquake and ASN records. In this study, the coherence of Rayleigh waves obtained from ASN and earthquake records is investigated in Adana region, southern Turkey.

## 3. Data Processing

We use the vertical-component continuous data (2010, January 2012, December) recorded at 6 broadband stations located in the Adana Basin (Figure 1). These stations are part of the two national networks operated by Kandilli Observatory and Earthquake Research Institute (KOERI) of Bosporus University and Earthquake Research Department (ERD) of Disaster and Emergency Management Presidency of Turkey.

We analyze the magnitude Ml = 5.0 Andirin earthquake occurred on 22.07.2012 at the depth of 7 km (Figure 1). The vertical-component seismograms are obtained from KMRS, KARA, YAYL, MERS and KIZK stations. Firstly, Rayleigh waves are selected and stored from the earthquake seismograms. Then Green's functions are retrieved for the same stations recording the Andirin earthquake, employing the ANDN station as a virtual resource.


**Figure 2.** Data processing procedure for Green's functions.

As the first step of data processing, we scanned the three years continuous data for time gaps that develop due to the interruptions in the data transmission and/or instrumental failure. In this step, we eliminated 35, 12, 39, 55, 44 and 37 percent of the data at stations ANDN, KMRS, KARA, YAYL, MERS and KIZK, respectively. In the calculation of the cross correlations, we made station pairs using ANDN station and other stations (ANDN-KMRS, ANDN-KARA, ANDN-YAYL, ANDN-MERS, ANDN-KIZK). We follow a data processing procedure similar to that used by Bensen et al. (2007) (Figure 2). First, the trend, mean and instrument response are removed from raw data, then the data is divided into 1-hour long segments. Then, down sampling (to 10 sps), low-pass filtering (50 s) and one-bit normalization and spectral whitening steps were performed respectively. After computing 1-hour cross correlations, we obtain monthly and yearly stacks. For the KIZK station the data processing steps results up to cross correlation are shown in the Figure 3. Cross correlation and monthly and yearly stacks for the ANDN-KIZK station pair are presented in the Figure 4. The waveform improved significantly with increasing stacking period.

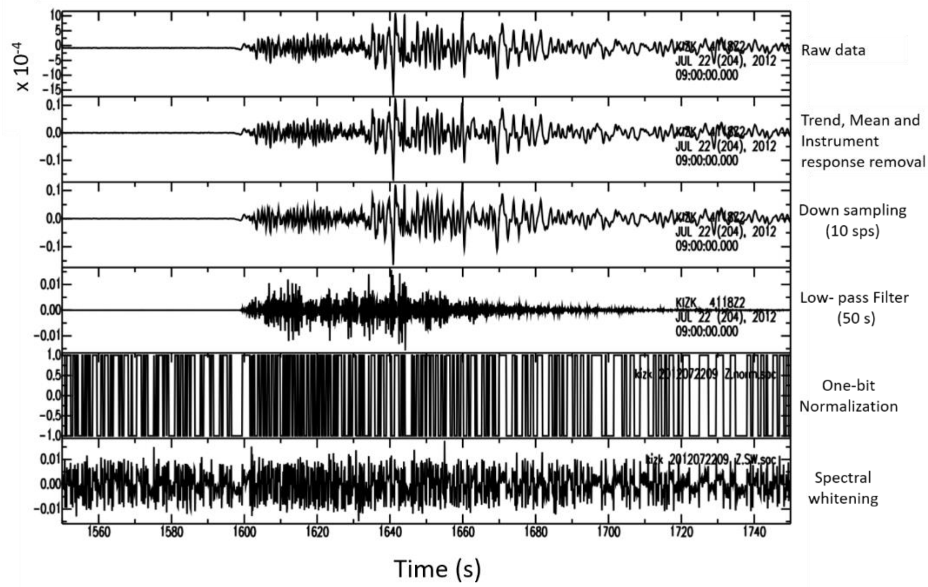


**Figure 3.** Data processing steps for KIZK station for 1-hour length data. (Zoom in 155-175 s)

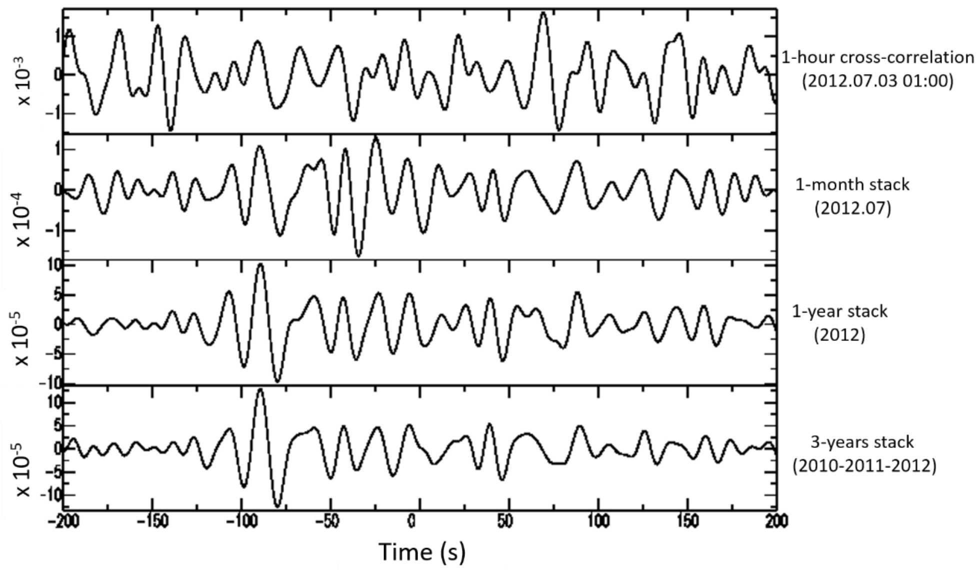


**Figure 4**. Cross correlation and stack results for the ANDN-KIZK station pair.
(All Green's functions are band-pass filtered between 10-50 sec)

## 4. Results and Conclusions

The record section of the Green's functions obtained for ANDN (reference station or virtual source) and the other 5 stations is shown in Figure 5. The Rayleigh waves are observed at positive and negative lags with minor discrepancy in amplitudes in the Green's functions. But the arrival time of the Rayleigh waves is almost same. We compute the symmetric signals by averaging of the positive and negative parts of the Green's functions to get better signal to noise ratio.

We selected the Rayleigh waves from the earthquake seismograms and compared them with the waveforms retrieved from the symmetric Green's functions (Figure 6, red signal: Earthquake, black signal: ASN). We observed that there is a remarkable match between the main peaks of the two waveforms, despite some very small differences between the phases of the secondary peaks. Thus, we conclude that the Rayleigh waves can reliably be obtained from the Green's functions. This suggests that the Rayleigh wave group velocities can be estimated accurately by using ASN data in this region.

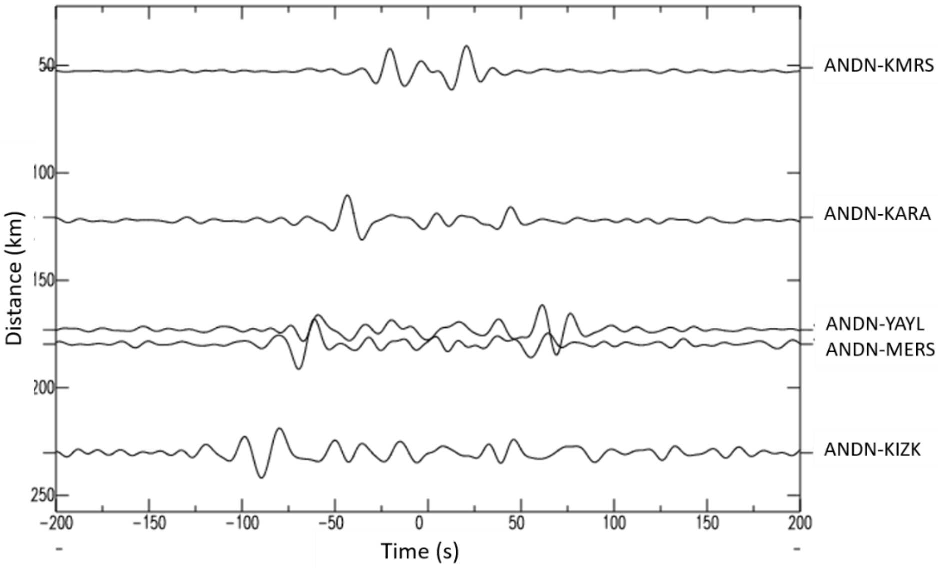


**Figure 5**. Record section of the Green's functions (ANDN: reference station.)

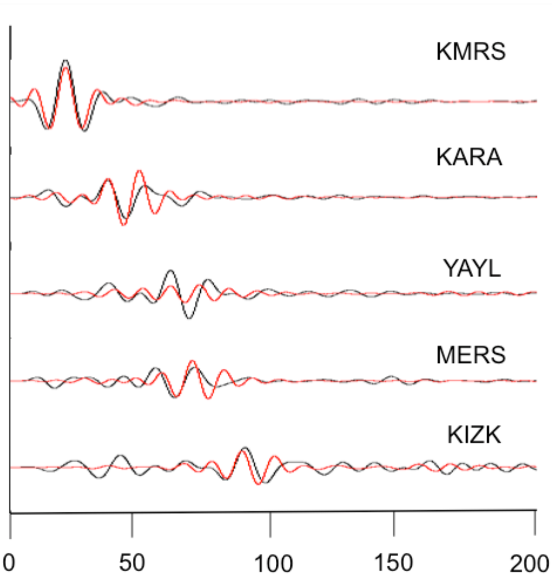


**Figure 6.** Observed Rayleigh waves (red waveform: earthquake, black waveform: Green's functions). All records are band-pass filtered between 8-30 s. The maximum amplitudes of the signals are normalized to be unity.

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### Conflict of Interest

No conflict of interest was declared by the author.

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