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Comparison of the Soil Dynamic Amplification Factor and Soil Amplification by Using Microtremor and MASW Methods Respectively

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Abstract. Single Station Microtremor method, which is widely used nowadays, is an effective and easy applicable method. In this study, dynamic amplification factor distributions of the study area were obtained using scenario earthquake parameters with single station microtremor data gathered at 112 points. In addition, a surface wave active method, which is known as MASW (Multichannel Analysis of Surface Waves), was applied at 43 profiles to calculate the soil amplification values. Dynamic amplification factor (DAF), soil amplification, the predominant soil period (PSP), geology and topography data of the study area were analysed together. Dynamic amplification factor and soil amplification values were obtained 2 or higher at about sea level parts of the study area which are generally composed of alluvial units. Additionally, in high altitude regions that are composed of volcanic rocks, relatively lower dynamic amplification factor and soil amplification values were obtained. The minimum amplification value in the study area was 1.15, while the maximum amplification value was 3.05 according to the dynamic amplification results and the soil amplification values were between 1.16 and 3.85 in harmony. It is seen that the obtained DAF values and the soil amplification values calculated from the seismic velocities are very similar to each other numerically and regionally. Because of this, it is concluded that the values of the soil amplification obtained by the MASW method and the calculated DAF values in this study are in harmony with each other. Although the depths of research in these two calculation methods are different from each other, the similarity of the results allows us to arrive at the result of how effective the ground layer is on the amplification. It has a great importance to calculate the amplification values and other dynamic parameters by in situ measurements for a planned plot because geological units can vary even at very short distances in heterogeneously distributed areas.

1. Introduction

Many engineering disciplines are collaborating in order to predict how the layers will behave during earthquakes, to examine the behaviours of structures during earthquake motion, to design earthquake durable structures, to minimize earthquake damages and to prevent the deadly consequences of earthquakes. Preliminary estimation of the parameters of the earthquake and the analysis of the behaviour of the soil layer are gaining high importance. Modelling earthquake and designing the structures accordingly to ground movements can minimize the life and property loss. It is necessary to plan what to do after the earthquake and to take precautions before the earthquakes come into play.

The parameters such as the predominant soil period, thickness and shear wave of the ground layer are important for clarifying the relationship between earthquake-ground-structure. The most important factor causing structural damages during an earthquake is the underestimation of the Peak Ground Acceleration (PGA) value. This means that with how much change will the earthquake acceleration emerging from the bedrock reach the soil surface cannot be predicted correctly. The ratio between the PGA value on the soil surface and the PGA in the bedrock is defined as Dynamic Amplification Factor (DAF). The DAF is a necessary parameter to estimate how much is the soil layer from the bedrock to the surface will magnify the earthquake effect. The DAF values can be computed with theoretical assumptions and calculations made in the frequency domain. DAF was calculated benefiting from previous studies [1, 2] using microtremor noise records and earthquake parameters (M (Magnitude), x (epicentre distance, H (depth), r (damping factor). For this purpose, correct prediction of the earthquake sources that will affect the investigation area (the earthquake scenario) and modelling of soil-bedrock parameters are required [3]. Although the earthquake phenomenon is a complex phenomenon that is very variable, it is very important to know about earthquake parameters by using geophysical methods before it happens.

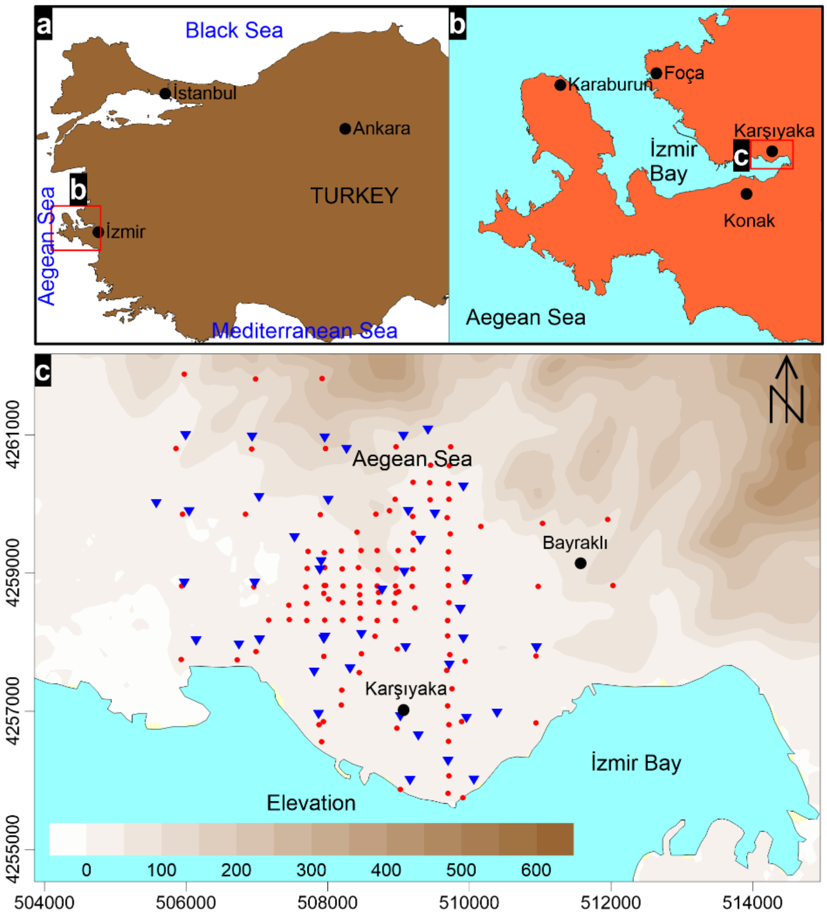

Figure 1. Study area location map. a) The western borders of Turkey b) Izmir city and its surrounding c) the topography map of the Karşıyaka and Bayraklı districts (the study area). The red circles indicate the recording locations of the microtremor method in the study area (112 points) and the blue triangles are the location of the MASW profiles (43 Profile)

According to the map of earthquake regions of Turkey, İzmir is located on the first-degree earthquake zone and is frequently affected by small and medium scale earthquakes. In this study, DAF changes were calculated in the study area using a single station microtremor method in the study area (figure 1.) located in the north of İzmir province and a scenario (target) earthquake where the seismic activity is high. The microtremor dataset is based on noise records recorded at 112 points. The earthquakes occurred at the surrounding of the study area between 2000 and 2017 years were examined at the USGS catalogue [4] according to this data the location and other earthquake parameters were selected for the scenario earthquake. MASW (Multichannel Analysis of Surface Waves), which is known as a surface wave method, was applied at 43 profiles to calculate the soil amplification (SA) values by using shear velocities. Calculated and obtained geophysical parameters (DAF, SA) were tried to be interpreted together. Geological and topography information was taken into consideration during interpretation.

2. Geology

The Bornova Melange (Upper Cretaceous), which overlies the basement rocks in the Izmir region, underwent intense tectonic deformation during and after sedimentation [5]. Bornova melange rocks are made up of interbedded sandstone–shale, limestone lenses, limestone and serpentinite bodies, mafic volcanics, chert and their complexes such as Dededağı and Kızılkalesi Formations. Neogene sedimentary rocks, consisting of conglomerate, sandstone, siltstone, mudstone and limestone, discordantly overlie the melange, and the contact between the melange and the Neogene units [6]. The volcanics of Yamanlar cover existing units unconformably. The Quaternary aged alluvial overlays all existing units unconformably at the study area [7]. The distribution of geological units (volcanic units and alluvium) in the study area are given in figure 2.

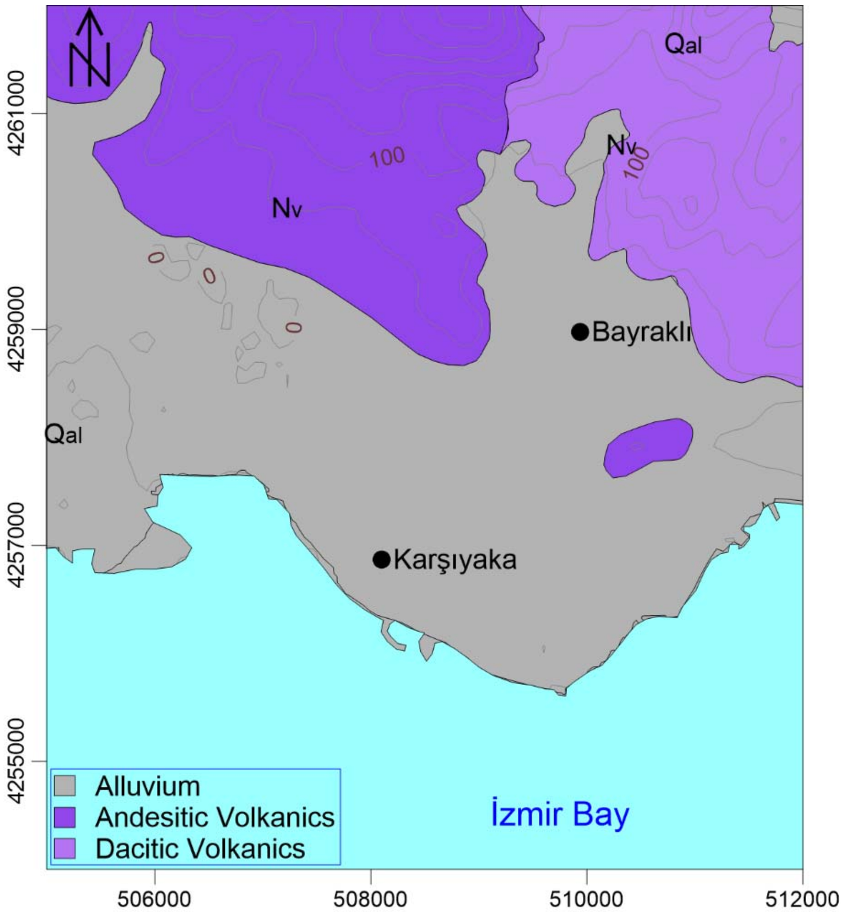

Figure 2. Geological units' distribution in the study area [8].

3. Methods and Calculations

3.1. MASW Method

The MASW field study was conducted on 43 profiles (figure 1). Measurements were applied with changing geophone spacing's of 1, 2.5 and 5 m, with 24 or 48 pieces of geophones according to the field conditions. Data sets were created using Geometrics Geode 24 Ch seismic receiver, 4.5 Hz P geophone and 100 lb Hydraulic Hammer as energy source. During the field study, sampling interval was set to 0.125 milliseconds and the recording time was 2 seconds. Data evaluation procedures were performed using the Seisimager program.

Considering that the top layer, sometimes very thin, may not always represent seismic amplification properly, several investigators [9, 10, 11] employed S-wave velocity averaged over surface soils spanning from the ground surface to a depth of 30 m, V_{S30}, as a key parameter to evaluate the soil amplification. They found V_{S30} to be an acceptably reliable index of soil amplification.

Midorikawa [10] showed the empirical relationship between the average shear-wave velocity and the soil amplification factor for peak ground velocity using the Japanese data. Midorikawa [10] have shown supportive evidence for empirical relationships between site amplification factor and V_{S30}. We calculated the SA values using Vs30 velocities obtained by using MASW method in the study area. The following equation; $SA = 68.Vs^{-0.6}$ (Vs < 1100 m/sec) described by Midorikawa [10] was used at this study because there are no V_{S30} velocities bigger than 1100 m/sec. Contour distribution maps of SA values were drawn after calculating the values and given in figure 3. Also, two sections described as A-A and B-B' were examined to observe changes of SA from north to south (figure 3).

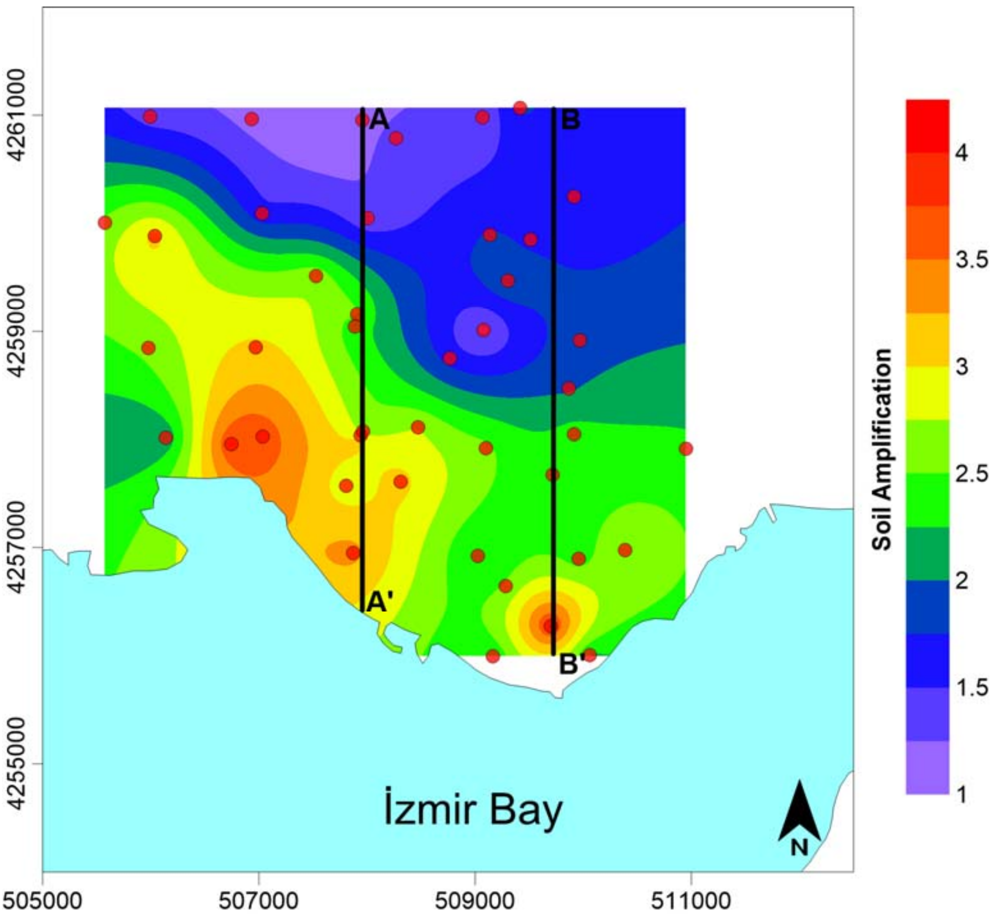

Figure 3. Contour distribution map for soil amplification in the study area and the two section lines (A-A', B-B')

3.2. Microtremor Method and DAF Calculations

In single station microtremor method, which was developed by Nakamura in 1989, the spectral ratio between the root-mean square average spectrums of the horizontal components over the spectrum of the vertical component was calculated. Nakamura assumes that there will not be too much variation in the amplitude of the vertical component in general and that the horizontal component waves will be affected by the ground properties. Nakamura Method [12]; the local effect due to the surface geology is found by the spectral ratio of the horizontal and vertical components. In recent years, the single-station microtremor method has been widely used. [3, 13, 14].

The microtremor measurements were recorded at a sampling interval of 100 Hz for a half-hour period. The work was carried out with the help of the Güralp brand CMG-6TD broadband recorder and auxiliary equipment (laptop computer, battery, bucket, etc.). Noise records were collected using a single instrument, with measurements made at each point being independent of each other and applied at 112 points in the study area (figure 1). The microtremor method used in the study has been taken into consideration in the previous studies [13, 15] with the data obtained by different geophysical methods and used to determine the dynamic properties of the grounds. The data evaluation phase is as follows; firstly, microtremor data were removed from the trend effect and band pass filter was applied at 0.05-20 Hz. The windows varying in length from 25 s to 80 s were selected and a 5% cosine taper was applied. The Fast Fourier Transform (FFT) is applied to each window to obtain the amplitude spectra of each component. Bandwidth b = 40 was selected for the obtained spectra and Konno-Ohmachi rounding was applied. At the last stage, the H / V spectral ratios were obtained by proportioning the horizontal component spectra to the vertical component spectrum.

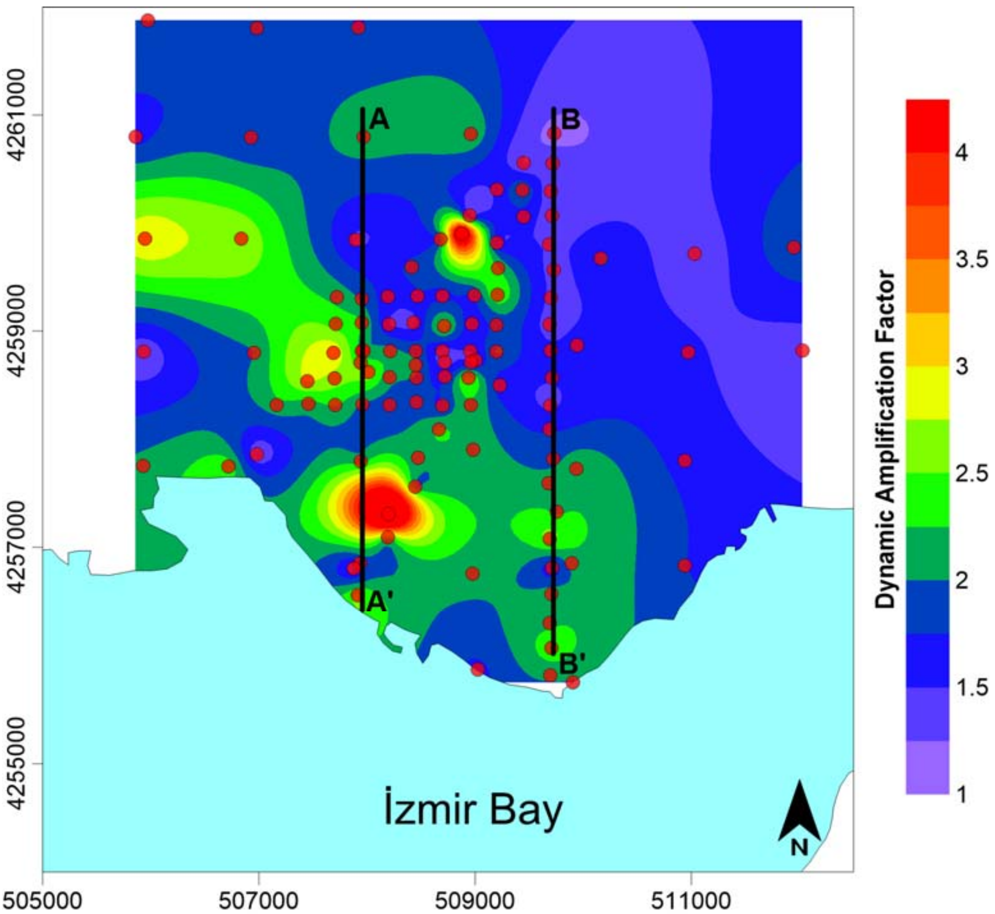

Figure 4. Contour distribution map for dynamic amplification factor in the study area and the two section lines (A-A’, B-B’).

In the scope of this study, DAF calculations were carried out at 112 points. The functions obtained by means of microtremor HVSR were used as soil transfer function while making calculation. An earthquake, whose selected magnitude was 7, hypocentre depth 30 km, and damping factor 0.6, was used as the earthquake scenario. Epicentre distance was selected 50 km, DAF values were calculated separately for each point, and DAF results were mapped in figure 4. A-A and B-B' sections on DAF contour map were evaluated to discuss the changings from north to south (figure 4).

4. Conclusions

According to the distribution contour maps of the both SA and DAF results, the DAF map is more complicated then SA map. Looking at the SA map it is clearly seen that the south part of the study area has a bigger amplification values and also DAF map gives similar results. The minimum amplification values are achieved at the northeast part of the study area so this part will not amplify very much a future earthquake effect. It is seen clearly especially in SA map that the maximum amplification values took place in the southwest part and minimum values were settled at northwest.

Looking at the graphic of the A-A' section which includes both DAF and SA variation from north to south it can be said that the changes are similar along the line (figure 5.). They look a little bit different at the beginning of the line but they become similar approaching to the 1000 meters at line. Also there is a mismatch at about 3750 meters. This unconformity may be studied in more detail in the future.

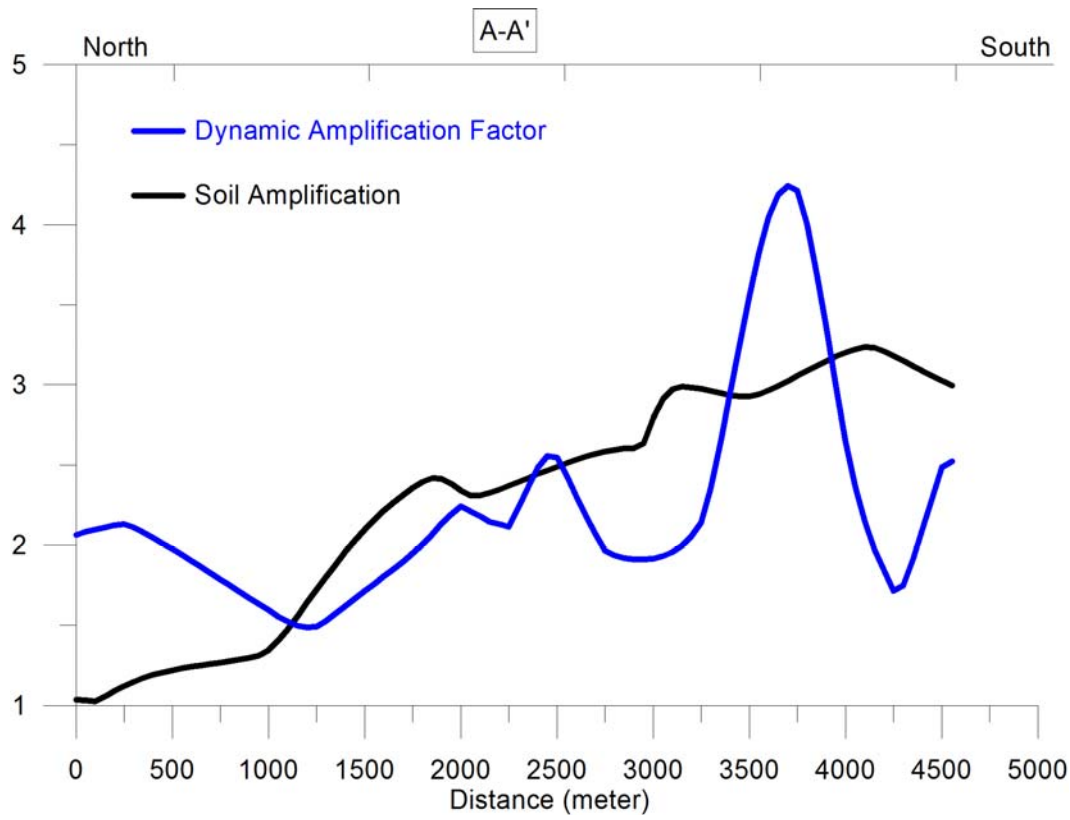

Figure 5. Variation of the DAF and SA parameters across the A-A' section line

DAF and SA values change very similar to each other at the B-B' section (figure 6.). We can say that the B-B' line is more compatible in itself that the A-A' line. Only there is a mismatch between 4000-4500 meters. The two amplification parameters are increasing from north to south.

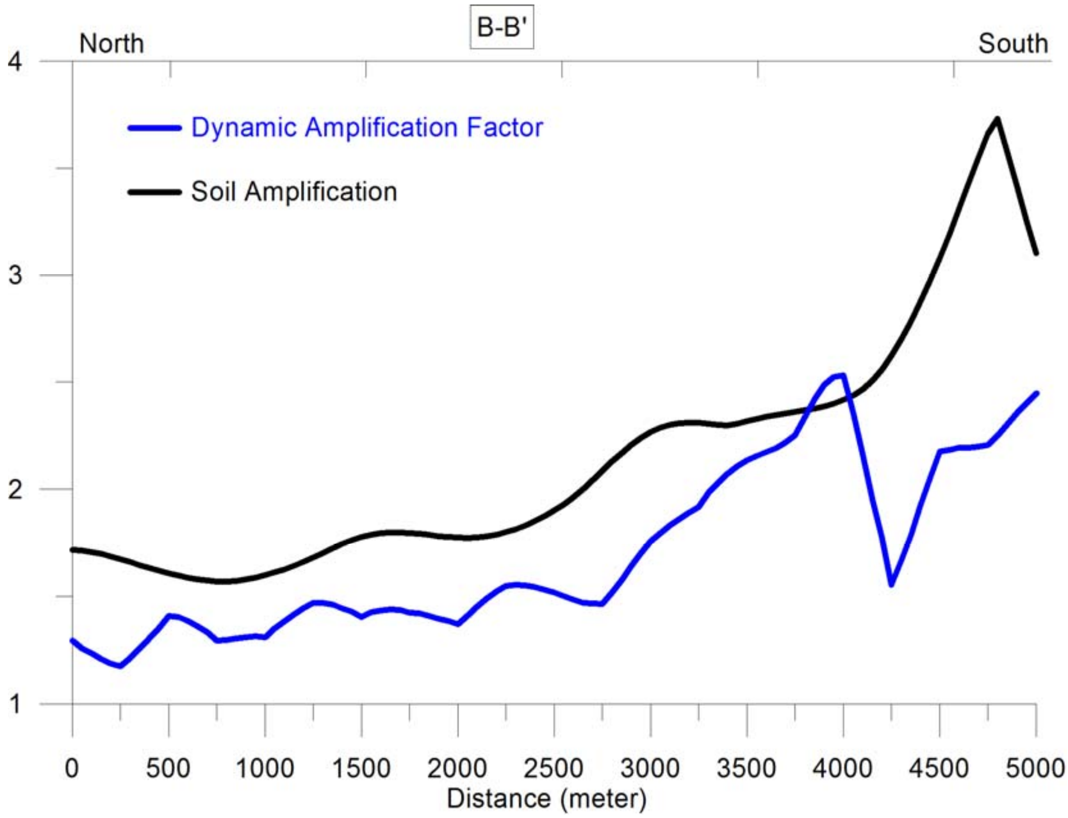

Figure 6. Variation of the DAF and SA parameters across the B-B' section line

Low implication values were obtained on the rock units at the north of the study area. On the contrary on the alluvium parts of the study area at the south it has been achieved high amplification values. Given these results the increasing of the DAF and SA parameters from north to south are compatible with the geology. According to the two section graphics, it can defined that the SA values are generally high from the DAF values along the lines.

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