

A PRELIMINARY STUDY FOR THE DISTANCE DEPENDENCE OF THE SPECTRAL DECAY PARAMETER κ FOR THE EUROSEISRISK STRONG MOTION ARRAY

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The Fourier amplitude spectra of selected accelerograms recorded by the 3D strong motion array at the EUROSEISRISK study area were used for the study of the distance dependence of the parameter κ . The parameter κ_0 for every recording site was also determined. In order to investigate the variation of κ_0 with the soil conditions the data were plotted for stations having the same conditions. The value determined for the stations located along the axis of the valley (thick deposits) was found equal to 85msec, for the station at “very stiff soil”, κ_0 found equal to 49 msec, and for the transition area at the edges of the valley the value was found equal to 66.5 msec.

Furthermore simple scaling relation holding between several spectral parameters as the frequency of the maximum amplitude, f_M and the frequency which corresponds to the 95% of the energy of the spectrum, f_{95} , and the kappa values were also determined.

The comparison of the data from the Euroseisrisk array and other areas of Greece shows that the Mygdonia graben, where the EUROSEISRISK array is deployed has the highest attenuation among the examined areas.

Keywords: Spectral Attenuation , kappa, EUROSEISRISK, strong motion array

INTRODUCTION

The importance of the shape and amplitude of the Fourier amplitude spectrum of acceleration was recognized as useful for various applications to earthquake engineering by the pioneering work of McGuire (1978). Hanks (1982) suggests that, in general the acceleration spectrum is flat above the corner frequency to f_{max} above which the spectrum decays rapidly. Anderson and Hough (1984) after the elaboration of several of spectral plots proposed that to first order the shape of the acceleration spectrum at high frequencies can generally be described by the equation:

$$\alpha(f) = A_0 e^{-\pi\kappa f} \quad f > f_E \quad (1)$$

where A_0 depends on source properties, epicentral distance and perhaps other factors. f_E is the frequency above which the spectral shape is indistinguishable from exponential decay.

Hough and Anderson (1988) assumed that the parameter κ is the sum of two terms:

$$\kappa = \kappa_0 + \int_{path} \frac{dR}{Q(f)\beta} \quad (2)$$

The term κ_0 is related to the attenuation of the vertical propagation between the bedrock and the surface, controls the amplitude spectral shape at high frequencies and is distance independent. The second term denotes the attenuation due to the propagation path, Q is the quality factor and β is the shear wave velocity. For an homogeneous half space (1.2) has the form:

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$$\kappa = \kappa_0 + \frac{R}{Q(f)\beta} \quad (3)$$

Papageorgiou and Aki (1983) suggested that the fall-off at high frequencies of observed spectra at a site may not be a propagation path effect but primarily a source effect.

Taking the logarithms of (1) and applying the least squares' technique to the data set, we can determine the κ_0 -value based on the slope of the linear fit to the data. This approach was applied in the present work.

DATA

The data set consists of the recordings of 63 earthquakes with equivalent magnitudes in the range $1.0 \leq M \leq 6.6$ and epicentral distances in the range of $1 \text{ km} \leq R \leq 199 \text{ km}$. During the period of the EUROSEISRISK project there were no records of earthquakes with $M \geq 6.0$ and epicentral distances $R \geq 40 \text{ km}$. Therefore in order to have a good coverage both in magnitude and distance good quality records from events recorded during the project EUROSEISMODE were used.

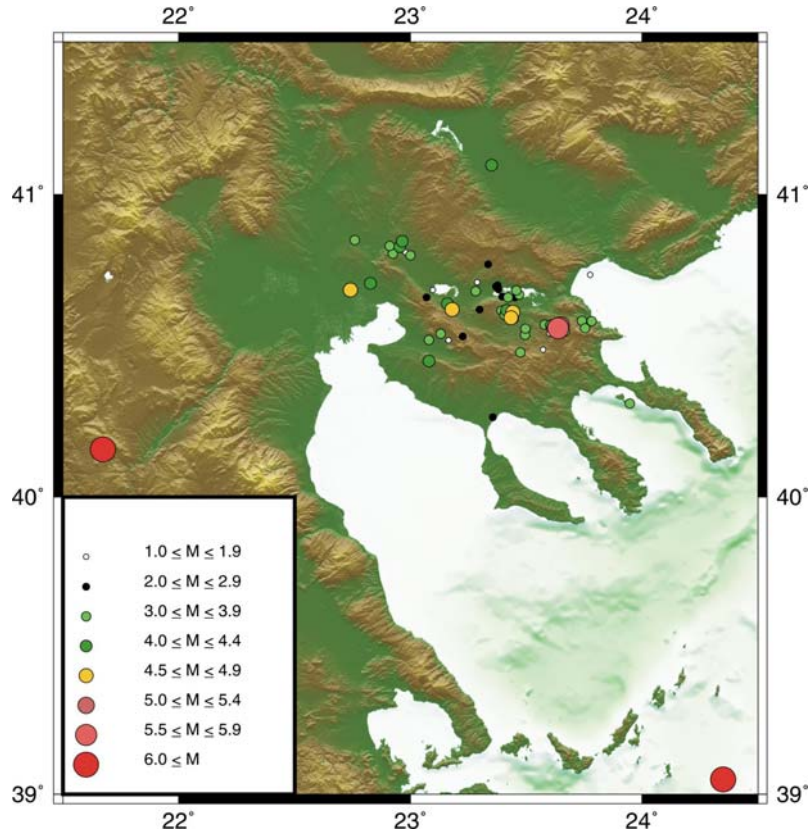


Figure 1. Geographical distribution of the epicenters of the earthquakes used in the analysis of the present study.

The map in figure (1) shows the geographical distribution of the epicenters of the earthquakes recorded by the array denoted by circles. The various colours and sizes of the circles represent the variation of the magnitude of the corresponding earthquakes as shown in the legend. The source parameters of these earthquakes were provided by the Laboratory of Geophysics (AUTH-GL). For the earthquakes occurred during the EUROSEISRISK project and triggered three or more strong motion

instruments the P- and S- arrival times of the records were used in a re-calculation procedure of the epicenters (Karayianni, 2005: personal communication) using the HYPOELLIPSE source code.

The quality of the records was strongly dependent on the type of the instruments used to equip the stations. Furthermore during the period of the network operation various types of instruments were used resulting in various formats. In order to process the data in a uniform way a computer code was developed for the data filtering, the selection of the proper time window and the determination of the spectral attenuation parameter, κ .

DATA ANALYSIS

All the strong motion records data were converted in simple ASCII format files including the acceleration values with step interval 0.005 sec corrected for the instrument response and offset. The analysis was carried out using an interactive tool, which enables the trial of various windows selection in the time domain for the analysis and at a second step the data elaboration in the frequency domain. The length of the window of the selected signal in the time domain depends on the epicentral distance and magnitude of the corresponding earthquake. The plots in figure (2) show three accelerograms and the time window selected for the calculation of the spectrum is marked by red brackets. The source to station distance is also given on the upper right corner, inside the frames with the time series.

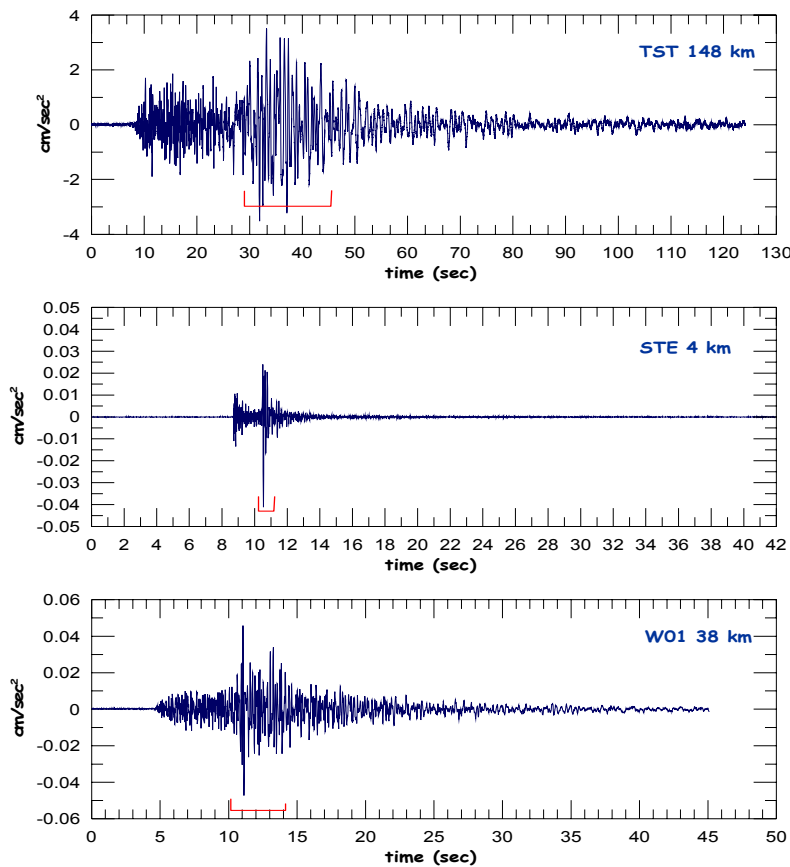


Figure 2. Accelerograms from three earthquakes recorded at various distances. The time window selected to calculate the spectrum is indicated with red brackets. The source-station distance is also indicated on the upper right corner, inside the frames with the time series.

The data analysis in the frequency domain resulted also in the estimation of the frequency f_{95} (:frequency which defines the upper limit of the frequency band including the 95% of the energy) and the frequency corresponding to the maximum amplitude of the Fourier spectrum f_M .

The plots in figures (3) and (4) show the dependence of the determined kappa values on the epicentral distance for the stations STE and STC located at very stiff soil conditions.

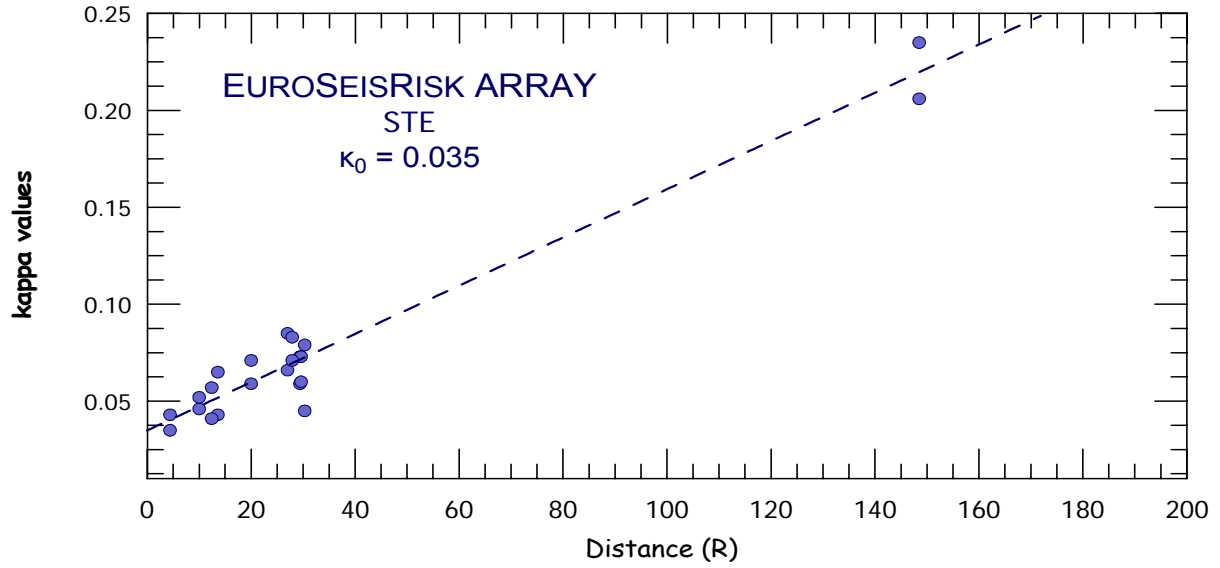


Figure 3. kappa values versus epicentral distance for the station STE (very stiff soil conditions)

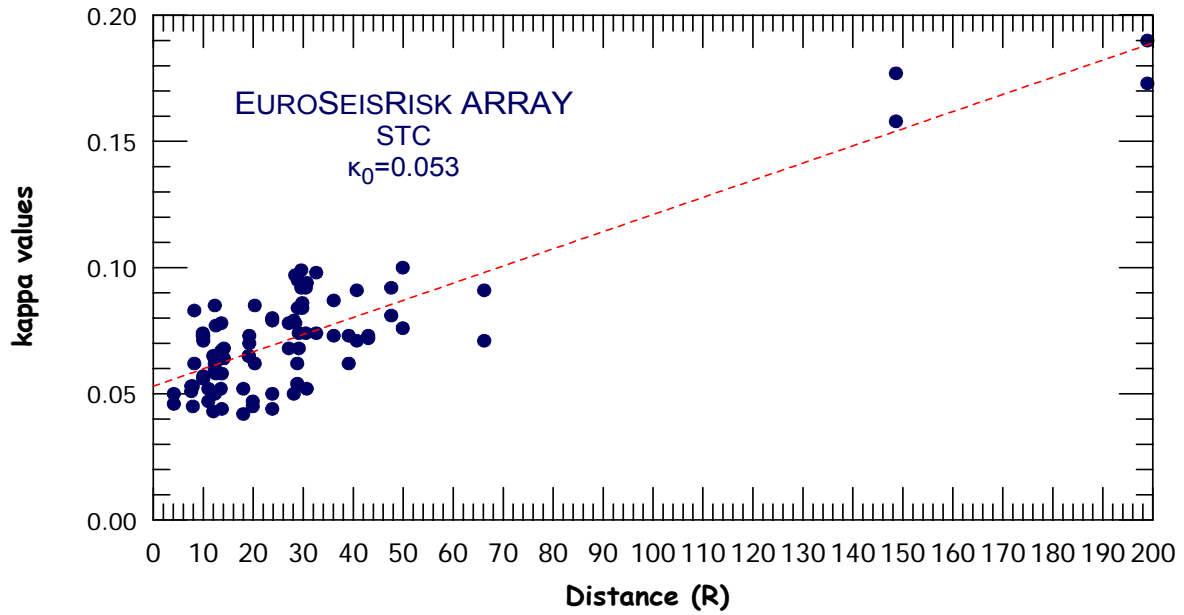


Figure 4. kappa values versus epicentral distance for the station STC (very stiff soil conditions)

If we use all the data of the two previous stations then the value of κ_0 for the set of 108 horizontal components is equal to 49 msec. The corresponding plot is shown in figure (5).

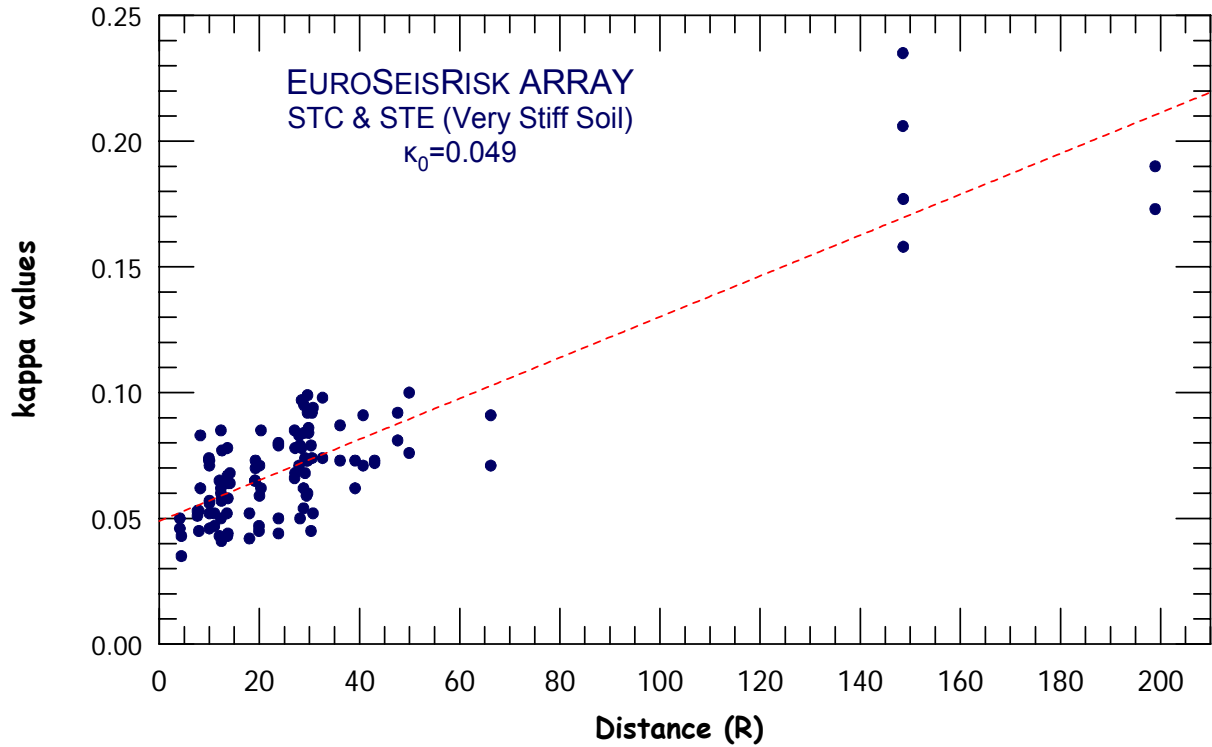


Figure 5. kappa values versus epicentral distance for 108 horizontal components of the strong motion instruments located at very stiff soil conditions.

At the centre of the valley there is the 2D test site (TST) array and detailed geophysical surveys were carried out for the determination of the velocity profile (Raptakis et al., 2000). Furthermore along the axis of the Mygdonia graben a network of high dynamic range strong motion instruments was installed during the EUROSEISRISK project. Unfortunately, the accelerograms recorded by the instruments installed during the EUROSEISRISK project do not cover either a wide range of epicentral distances or of magnitude range. Therefore the use of these records for the κ_0 determination may lead to erroneous results. Moreover many of the records were influenced by high noise due to agricultural works in the area and they cannot be analyzed. The plot in figure (6) shows the kappa values as a function of epicentral distance for a set of good quality data. Most of the data are from the TST instrument and different symbols were used to denote the three different data sets as it is shown in the figure legend. Considering the station location and the bedrock depth (Savvaidis et al., 2004) we can observe that the κ -values for the station W003 which is located at thicker deposits are higher than the values determined for the two other sites. Using the whole data set the determined value for the stations located on alluvium was found equal to $\kappa_0 = 85$ msec. This is a high value for κ_0 which is related either to the data process (window selection, frequency band selection for the estimation of kappa) or to the accuracy of the epicenters.

The 2D array at the TST site provided 130 horizontal components, which were used in the spectral analysis for the calculation of the corresponding kappa values and the plot for the distance dependence of kappa. These plots are shown in the figure (6).

Another possible reason which is related to the data elaboration but it is controlled by the source properties, is the existence among the sample of many small magnitude records. The S-wave window of those records has small duration which results in large frequency steps in the corresponding Fourier spectrum and therefore the estimation of the slope is not a robust one.

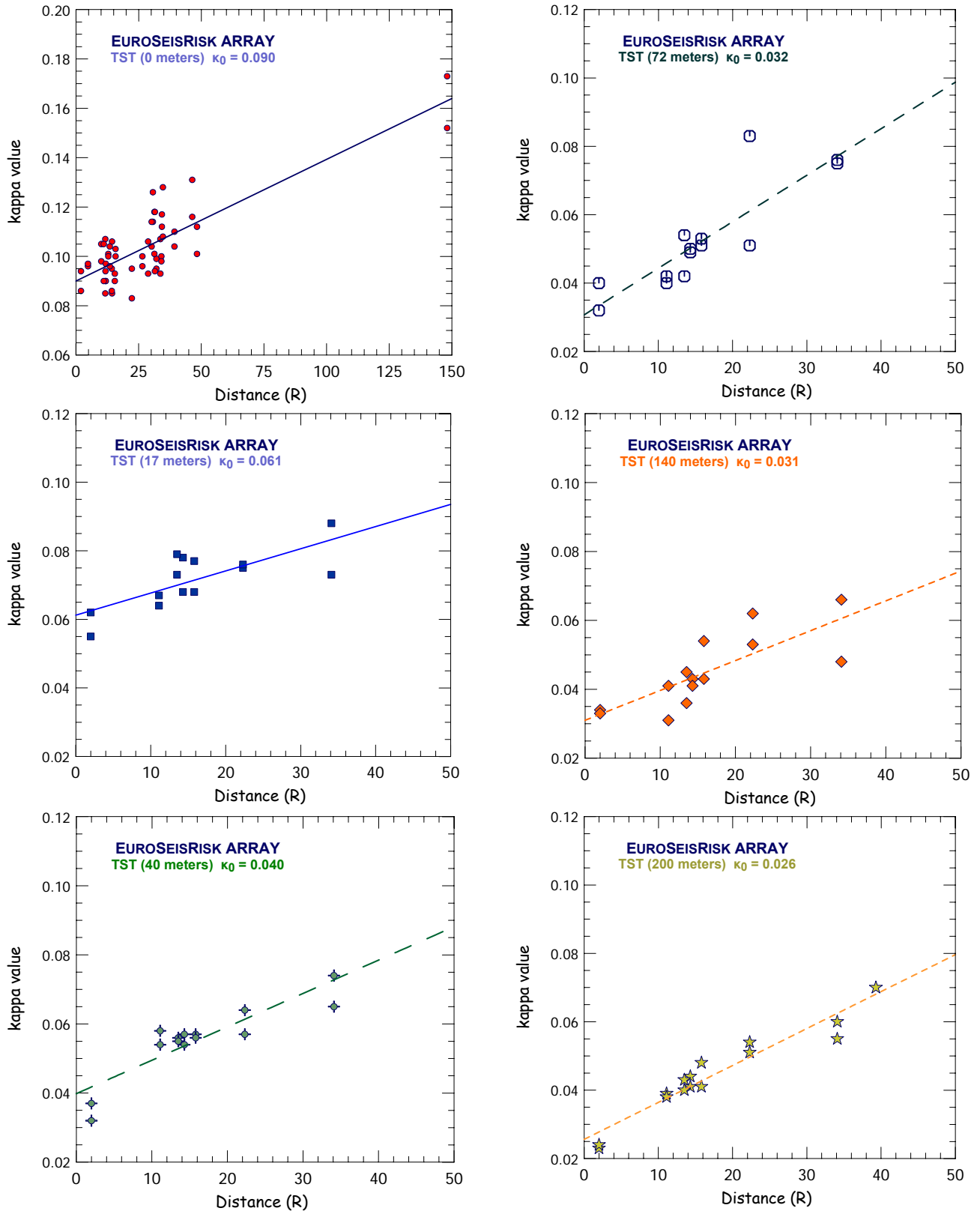


Figure 6 Variation of the distance dependence of kappa at various depths for TST recording site.

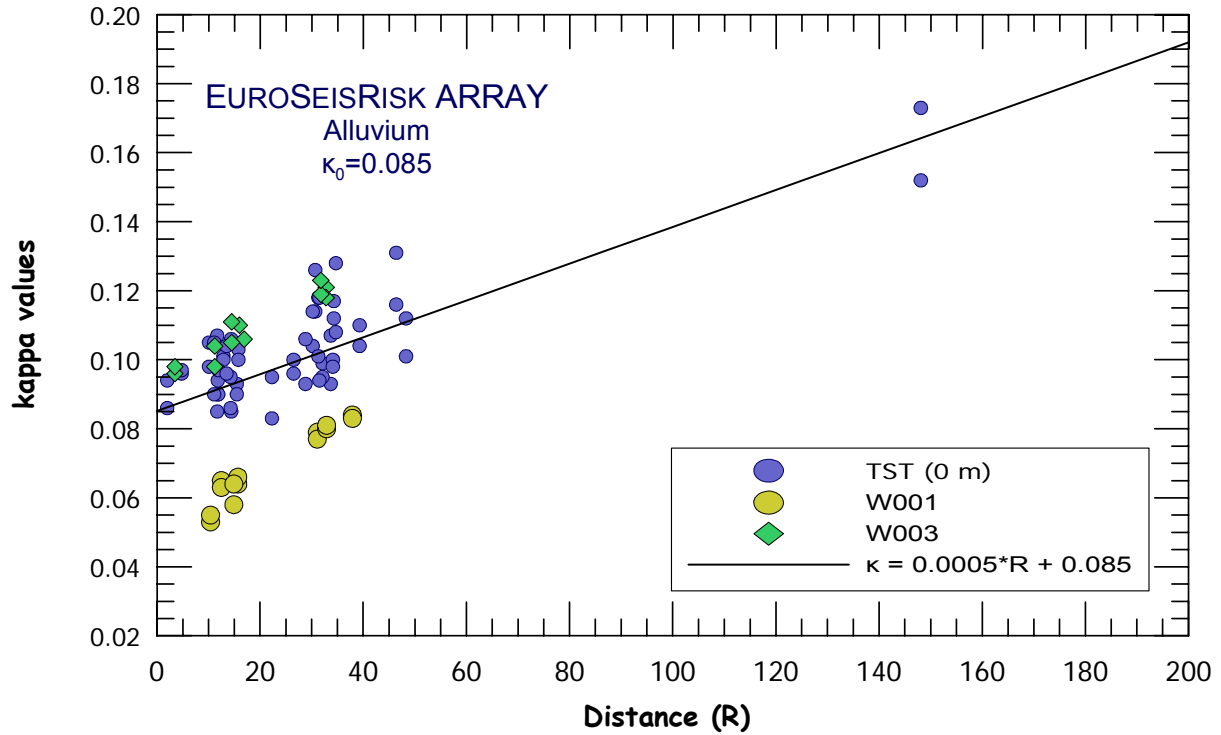


Figure 7. Dependence of the kappa values on the epicentral distance for 84 horizontal components of the strong motion instruments located at alluvium.

Two of the stations, namely BUT and FRM, are located at the edge of the valley between the two previous couples of stations. The background noise level is high and the number of the recorded accelerograms is very limited. If we consider the records of the two stations as a common set there are 18 horizontal components which were analysed in the frequency domain for the calculation of the corresponding kappa values and the distance dependence of kappa. The corresponding plot is shown in the figure (8).

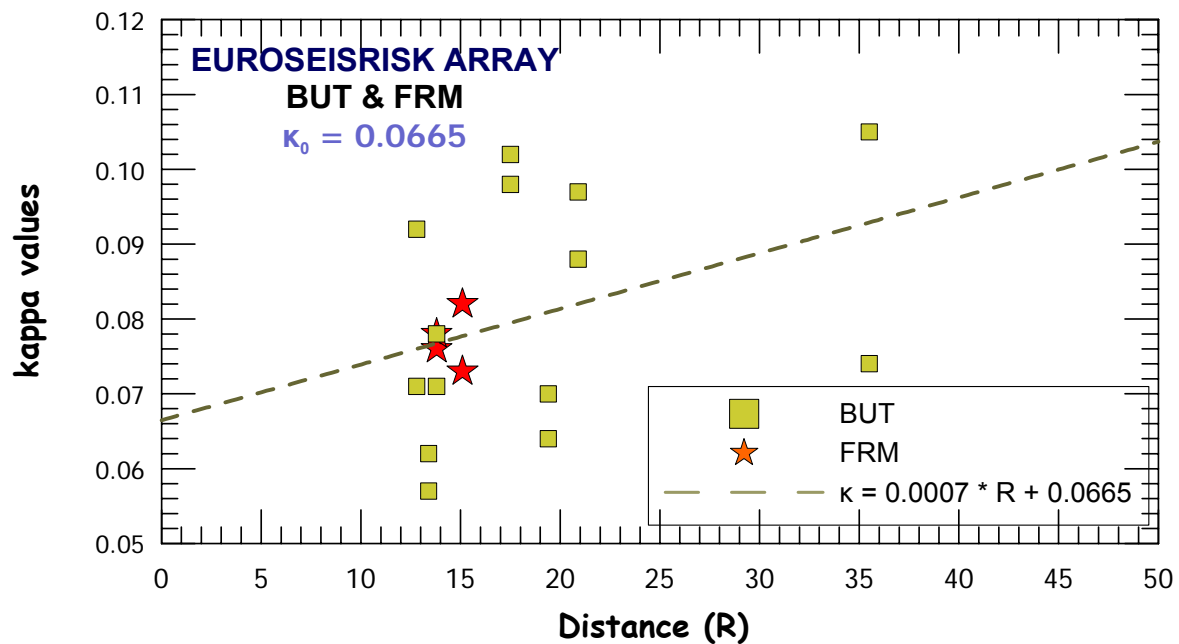


Figure 8. Plot of the kappa values versus epicentral distance for 18 horizontal components of the 2 strong motion instruments located at the edge of the valley.

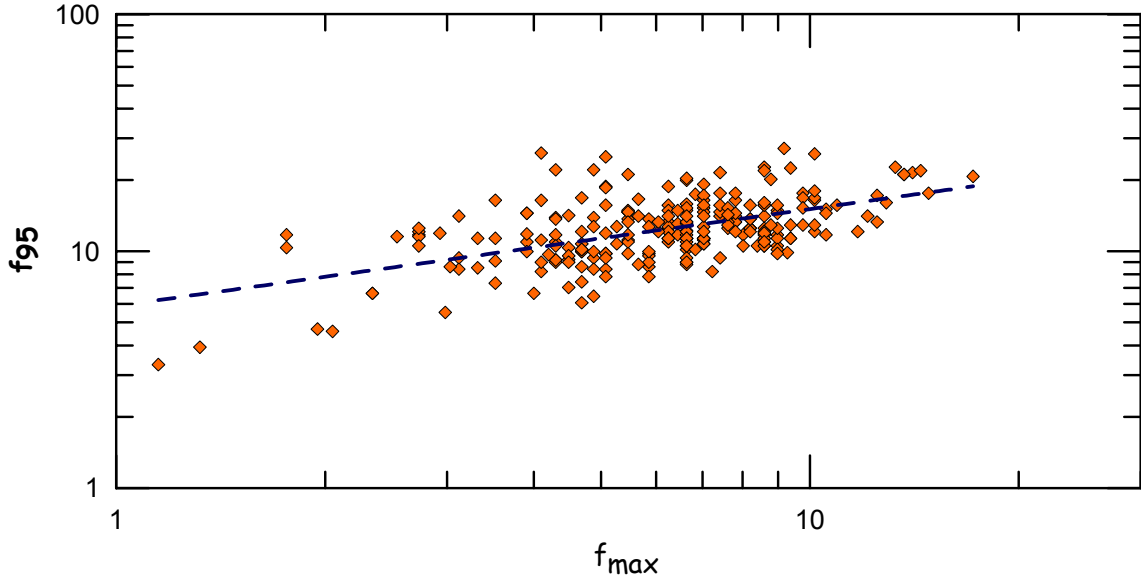


Figure 9. Plot of the frequency f_{95} values versus the corresponding values of f_M

In the spectral analysis two frequencies can be determined. The frequency of the maximum amplitude, f_M and the frequency which corresponds to the 95% of the energy of the spectrum and is denoted by f_{95} . These two frequencies were determined for all the records, which were elaborated. Figure (9) shows a plot of the f_{95} values versus the corresponding values of f_{MAX} . As can be observed from the plot in figure (9) the logarithms of these values shows a linear trend and the data can be fitted by a relation of the form:

$$\log F_{95} = 0.409 * \log F_M + 0.768 \quad (4)$$

The plot in figure (10) shows the distribution of the estimated kappa values versus the frequency f_{95} . The data for the strong motion sensors at the surface, the 140 and 200 m depth at the TST site are marked with red, green and yellow circles. It is observed that this relation depends on the depth. Similar results were found following the Athens 1999 earthquake (Papaioannou, et al., 2001).

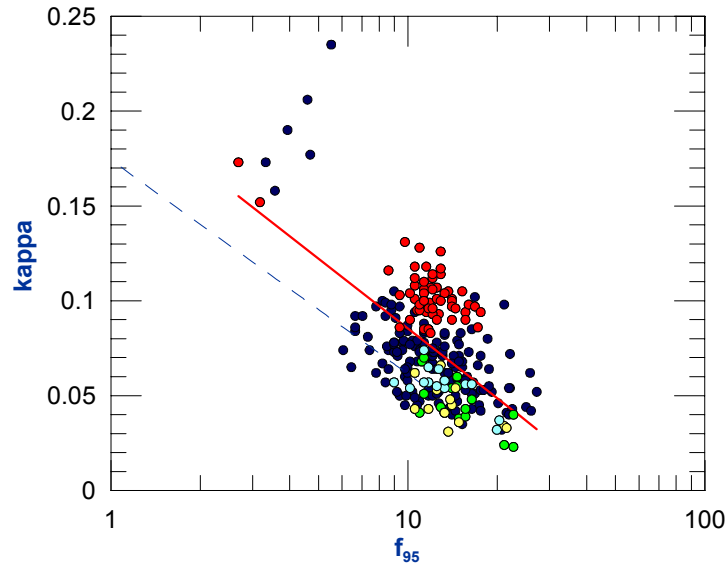


Figure 10. Spectral decay parameter, κ , as a function of the frequency f_{95} . The coloured circles stand for the records obtained at free-field, and at depths of 140 and 200m at the center of the valley.

Considering that the frequency f_{95} depends on the local site effects, in a first approximation we may assume that there is linear relation between the data. The line that fits to the data has the following equation:

$$\kappa = 0.208 - 0.053 * \ln f_{95} \quad (5)$$

The dashed line in figure (10) represent the relation holding for the data of the records of the main shock following the Athens 1999 earthquake (Papaioannou et al., 2001) and is shown for comparison.

DISCUSSION

The spectral decay technique was used for the estimation of the decay parameter κ of the high frequency acceleration spectra. The data set used consists of 272 horizontal components obtained at epicentral distances in the range of $1 \text{ km} \leq R \leq 199 \text{ km}$. Following the spectral analysis of the waveforms relations holding for the distance dependence of κ were determined for various soil

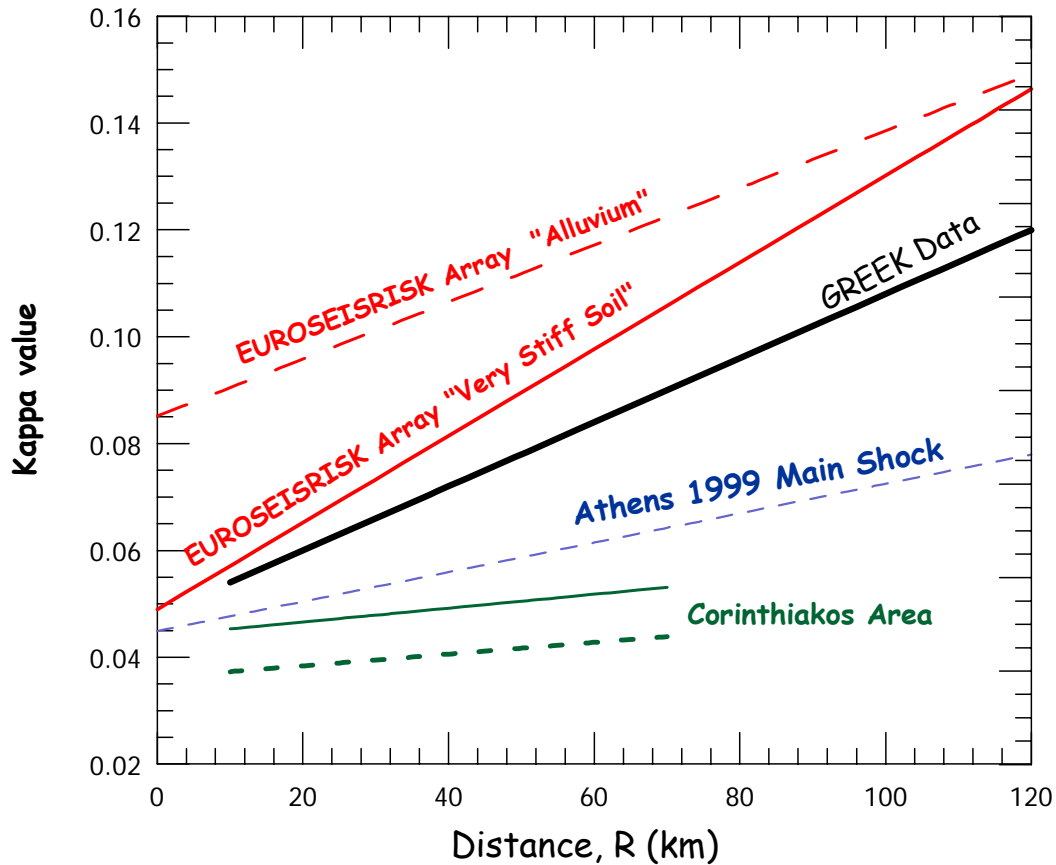


Figure 11. Spectral decay parameter, κ , as a function of the epicentral distance for alluvium and very stiff soil sites. The corresponding attenuation lines from other areas of Greece are also shown for comparison.

types. The plot in figure (11) shows the results for the EUROSEISRISK array (red lines) and the results obtained for the Greek area (black line: Hatzidimitriou et al., 1993), the Corinthiakos Gulf (green lines: Tselentis, 1993) and Attiki (blue line: Papaioannou et al., 2001). The comparison shows that the Mygdonia graben, where the EUROSEISRISK array is deployed has the highest attenuation among the examined areas.

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