

**SIMULATION OF STRONG GROUND MOTION USING EMPIRICAL GREEN'S
FUNCTION METHOD. PRELIMINARY RESULTS FROM AN EXPERIMENT IN GREECE**

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A B S T R A C T

Using the empirical Green's function method, ground motion for large earthquakes can be simulated by summing properly small event records. During July and August 1991, a network of 60 portable digital stations was installed in the area of Rio-Antirio (Greece) for the seismo-tectonic study and the evaluation of the seismic risk of the region. Among them, 12 6-channel portable digital stations (REFTEK) were installed aiming the recording of velocity and acceleration of earthquakes of different magnitudes in different sites in order to identify empirical Green's functions. Among the almost 5000 events that were localised from the seismotectonic group, 600 earthquakes have been selected that were recorded at least to 4 Reftek stations with magnitudes M_l varying from 1.0 to 4.0 .

In order to be able to compare the synthetics produced by this method with the observed earthquakes, a strong motion network of 8 SSA1 and 7 SMA1 stations was also installed in the same sites and remained in operation until September 1992, providing 453 accelerograms from 100 earthquakes with magnitudes ranging between 2.8 and 5.0 .

Simulations of a magnitude 4.5 event have been done for three stations with hypocentral distances ranging between 10 and 15 km, by using the recordings of a smaller event of magnitude 3 that comes from the same fault, giving a good fit to the observed recordings. In order to justify the use of the small events for the construction of a larger earthquake, a study of their waveform stability has also been done.

**ΕΞΟΜΟΙΩΣΗ ΙΣΧΥΡΗΣ ΕΛΑΦΙΚΗΣ ΚΙΝΗΣΗΣ ΧΡΗΣΙΜΟΠΟΙΩΝΤΑΣ ΤΗΝ ΜΕΘΟΔΟ
ΤΩΝ ΕΜΠΕΙΡΙΚΩΝ ΣΥΝΑΡΤΗΣΕΩΝ GREEN. ΑΡΧΙΚΑ ΑΠΟΤΕΛΕΣΜΑΤΑ ΑΠΟ ΕΝΑ
ΠΕΙΡΑΜΑ ΣΤΗΝ ΕΛΛΑΔΑ**

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Π Ε Ρ Ι Λ Η Ψ Η

Χρησιμοποιώντας την μέθοδο των εμπειρικών συναρτήσεων Green μπορούμε να επιτύχουμε την εξομοίωση της εδαφικής κίνησης μεγάλων σεισμών αθροίζοντας κατάλληλα τις αναγραφές μικρών σεισμών. Κατά τους μήνες Ιούλιο και Αύγουστο 1991, εγκαταστάθηκε στην περιοχή Ρίου-Αντιρρίου δίκτυο αποτελούμενο από 60 φορητούς ψηφιακούς σειсмоγράφους με σκοπό την σεισμοτεκτονική μελέτη καθώς και την εκτίμηση της σεισμικής επικινδυνότητας της περιοχής. Μεταξύ αυτών, εγκαταστάθηκαν και 12 φορητοί ψηφιακοί σειсмоγράφοι 6 συνιστωσών, (REFTEK), προσδοκώντας την καταγραφή της ταχύτητας και επιτάχυνσης σεισμών διαφορετικών μεγεθών σε διαφορετικές θέσεις με σκοπό την αναγνώριση εμπειρικών συναρτήσεων Green. Ανάμεσα στους περίπου 5000 σεισμούς που εντοπίστηκαν από την σεισμοτεκτονική ομάδα, διαλέχτηκαν 600 οι οποίοι είχαν αναγραφεί σε περισσότερα από 4 REFTEK, με μεγέθη M_L που κυμαίνονται ανάμεσα σε 1 και 4.

Για να είμαστε σε θέση να συγκρίνουμε τα συνθετικά επιταχυνσιογραφήματα με πραγματικές αναγραφές, εγκαταστάθηκε επίσης ένα δίκτυο επιταχυνσιογράφων (8 SSA1 και 7 SMA1) στις ίδιες θέσεις και έμεινε σε λειτουργία έως τον Σεπτέμβριο 1992, δίνοντας 453 επιταχυνσιογραφήματα από 100 σεισμούς με μεγέθη που κυμαίνονται ανάμεσα σε 2.8 και 5.0.

Εξομοιώσεις ενός σεισμού μεγέθους 4.5 έγιναν για τρεις σταθμούς με υποκεντρικές αποστάσεις που κυμαίνονται ανάμεσα σε 10 και 15 χιλιόμετρα, χρησιμοποιώντας τις αναγραφές μικρότερου σεισμού μεγέθους 3 προερχόμενο από το ίδιο ρήγμα, παρουσιάζοντας μεγάλη ομοιότητα με τις πραγματικές αναγραφές. Για να δικαιολογήσουμε την χρήση των μικρών σεισμών στην κατασκευή μεγάλων, έγινε επίσης μελέτη της χωρικής σταθερότητας των κυματομορφών.

INTRODUCTION

The empirical Green's function method was originated by Hartzel (1978), and has been successfully developed by combining it with the scaling law of earthquakes (Irikura, 1983, 1986; Wu et al., 1984; Irikura and Aki, 1985; Houston and Kanamori, 1986; Joyner and Boore, 1986; Boatwright, 1988; Takemura and Ikeyama, 1989).

The idea of this method is that the small earthquakes are carrying the message of their path and site geologic inhomogeneities because they are independent of the source-time function. All the authors inherently assume that the impulse responses for all portions of the fault area are provided by the smaller earthquakes. In modeling, the smaller events are time delayed, scaled in order to follow the ω -squared spectral scaling model and summed to simulate finite rupture.

In Elastodynamics Green's function is called the displacement field produced by the simplest of the sources, (the unidirectional unit impulse), which is localised precisely in both space and time. In the original idea of the method, the small earthquake used in the summation should correspond to an event of a very small magnitude. In that case the source function can be approached by a Dirac impulse and the recording can be

considered like a "real" Green's function. However, accurate records from smaller events may be restricted to a narrower and higher frequency range, because amplitudes at low frequencies become smaller than those of ground noise. This becomes even more difficult in the simulation of acceleration because of the limitations produced by the dynamic response of the accelerographs. Thus, in order to synthesize large earthquake motions, we have to use records from small earthquakes larger than appropriate sizes.

So empirical Green's functions have generally been defined as recordings of earthquakes some magnitudes lower than the earthquake being studied, having corner frequencies higher than the frequency range of interest and located nearby. They have been used in order to introduce path and site information in theoretical calculations.

In this paper, using the developed method proposed by Irikura (1986), we show the first results of some simulations for medium-size events, in order to test the validity of this method in Greece.

SIMULATION METHOD

In order to determine the total number of the subevents that have to be summed to synthesize the earthquake, the similarity scaling laws are used. If we suppose that the small event is represented by a circular fault of radius a and the target event by a square fault with length L and their displacement discontinuities d and D respectively, their seismic moments m_0 and M_0 are given by the expressions :

$$m_0 = \mu \pi a^2 d \quad \text{and} \quad M_0 = \mu L^2 D \quad (1)$$

Assuming a constant stress drop $\Delta\sigma$ for the small and the large event, we have:

$$\Delta\sigma \propto \frac{d}{a} \propto \frac{D}{L} \quad (2)$$

If the fault length L of the large event is N times more the length l of the small event, ($L=Na$), the constant stress drop condition implies that the dislocation d of the small event must be N times smaller than the total dislocation D on the main fault. Thus, the seismic moments m_0 and M_0 are scaled by the factor N^3 :

$$M_0 = N^3 m_0 \quad (3)$$

This means that for the modeling of the main shock, the total number of the subevents that have to be summed is N_3 and can be found by the ratio of seismic moments M_0/m_0 . Generally the similarity scaling laws, (Kanamori and Anderson, 1975; Geller, 1976) assume :

$$\frac{L}{l} = \frac{W}{w} = \frac{D}{d} = \frac{t_D}{t_d} = \left(\frac{M_0}{m_0} \right)^{\frac{1}{3}} = N$$

where t_D and t_d are the rise times of the big and the small earthquakes respectively.

We consider a rectangular fault (length L , width W) that represents the fault of the large earthquake to be simulated, (fig.1). The fault plane is divided into $b \times m$ elements representing the fault dimensions of the small events used as empirical Green's function. In order to build up the seismic motion of the large event, time delays between the summed seismograms are computed, considering that rupture propagates with a constant velocity and with a circular rupture front.

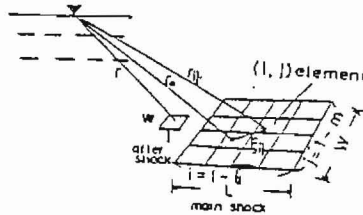


Fig.1. Schematic source model.

In order to model the slip motion at each subevent of the fault, a non-zero rise time t_d of the small event must be considered. So the slip function of the large event is built up by adding the n elementary slip functions lagged by the small event rise time t_d , (fig.2). So the total number of the summations is $b \times m \times n = N_3$. Moreover, before the summation, a correction of the radiation pattern is done for each element of the fault. Thus, the synthetic motion U for the large earthquake is given using the observed seismogram u of the small earthquake as:

$$U(x, t) = \sum_{i=1}^b \sum_{j=1}^m \sum_{k=1}^n \frac{F_{ij}^s}{F_0^s} \frac{r_{ij}}{r_0} u(x_0, t - t_{\xi} - t_d) \quad (5)$$

where $t_{\xi} = r_{ij}/v_s + \xi_{ij}/v_r$, and $t_d = (k-1)t_0/n$, F_{ij}^s and r_{ij} are the radiation pattern and the focal distance for (i, j) subfault element. For travel time corrections the shear wave velocity v_s is used in order to represent correctly the most energetic and destructive S waves.

In (5), the term of the uniform time shift t_d that is used in order to build the dislocation time function of the large earthquake, introduces to the synthetic an artificial periodicity of t_0/n . To avoid this artificial periodicity Irikura (1983), divided t_0/n by a n' in order to shift this periodicity in higher frequencies out of the frequency range of interest. So the

summation with respect to k in the expression (5) becomes:

$$\frac{1}{n'} \sum_{k=1}^{nxn'} u(x_o, t-t_{\xi} \frac{(k-1)t_D}{nn'}) \quad (6)$$

The synthetics produced by using (5) and (6) gave a good fit to the observed but only in low frequency motions up to $1/t_D$. However, the high frequency motions were underestimated. Muramatu

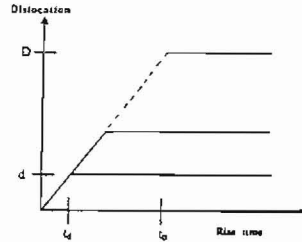


Fig.2. In every elementary source, the slip function is modeled by a ramp with dislocation D and rise time t_D .

and Ohnuma, (1985), and Yoshikawa et al., (1985), instead of dividing the term t_D/n , they assumed random time shifts, that is, the term t_D in the relation (5) is replaced by $(k-a_k)t_D/n$, where a_k are uniform random numbers between 0 and 1. Then the summation with respect to k in expression (5) becomes:

$$\sum_{k=1}^n u(x_o, t-t_{\xi} \frac{(k-a_k)t_D}{n}) \quad (7)$$

By this method of random time shifts the high frequency motions of the synthetics are overestimated. In order to obtain the synthetic which is consistent with spectral scaling at high frequencies, only N^2 records should be summed randomly for the case with the moment ratio of N^3 .

Finally Irikura (1986), proposed a revised method combining (5), (6) and (7) with an expression given by:

$$U(x, t) = \sum_{i=1}^b \sum_{j=1}^m \frac{F_{ij}^s}{F_o^s} \frac{r_o}{r_{ij}} u(x_o, t-t_{\xi}) + \sum_{i=1}^b \sum_{j=1}^m \sum_{k=1}^{(n-1)} \frac{F_{ij}^s}{F_o^s} \frac{r_o}{r_{ij}} \frac{1}{n} u(x_o, t-t_{\xi} \frac{(k-1)t_D}{nn'}) \quad (8)$$

The first term produces an ω^{-2} high frequency spectral fall off, while the second term produces an ω^{-3} fall off. Therefore, high frequency motions come from the first term with the summation of N^2 records, assuming $b = m = n = N$. Expression (8) is the one adopted for modeling in this paper.

DATA

During July and August 1991, a network of 60 portable digital stations (26 one-component and 34 three-component) was installed in the area of Rio-Antirio (Greece) and has recorded 5000 events. Among them, 12 6-channel REFTEK were especially installed for the recording of the acceleration of small earthquakes from different sites in order to test the validity of the empirical Green's function method and the study of the spatial variation of the waveforms of the small earthquakes. Almost 600 very well-located (0.5 km) events have been selected that were recorded at least by 4 Reftek stations with magnitudes M_L ranging between 1.0 and 4.0 (fig. 3).

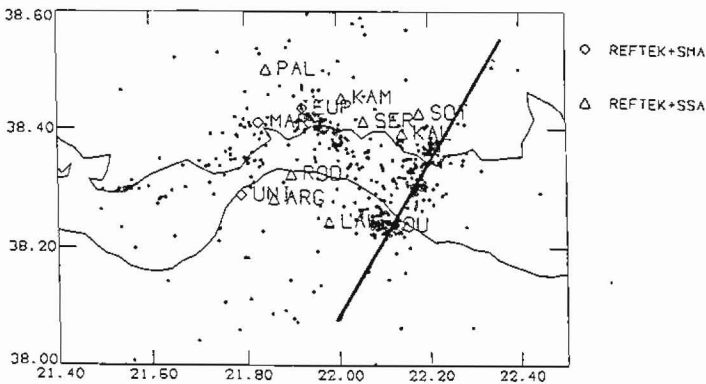


Fig.3. Strong motion network-REFTEK data (July-August 1991).

In order to compare the synthetics produced by this method with some relatively large earthquakes, another network of 8 SSA1 (3-component digital accelerographs) and 7 SMA1 (3-component analogue accelerographs), was installed in the same sites as the REFTEK stations and remained in operation until September 1992, providing 453 accelerograms from 100 earthquakes that have been recorded with magnitudes varying from 2.8 to 5.0. The localisations of the SSA1 data after August 1991 have been done using the S-P arrivals of the acceleration recordings (fig. 4). This big database with very good quality data combined with detailed seismotectonic information is probably one of the best dataset for the evaluation of this method. For the first test of the method the largest recorded earthquake that occurred within the network, an event of magnitude 4.5 (25 Oct. 1991), has been chosen as the target earthquake to simulate. Another event of magnitude 3 (2 Aug. 1991) that was recorded nearby has been chosen as the element event (fig. 4).

SIMULATION EXAMPLES

For the simulation of the 4.5 event, the model shown in figure (5) is used for all the examples. The correlation coefficient, the peak acceleration ratio and the spectral ratio

between the synthetic and the observed waveforms, are the parameters used to test the validity of the simulation. Seismotectonic results have been used in order to define the

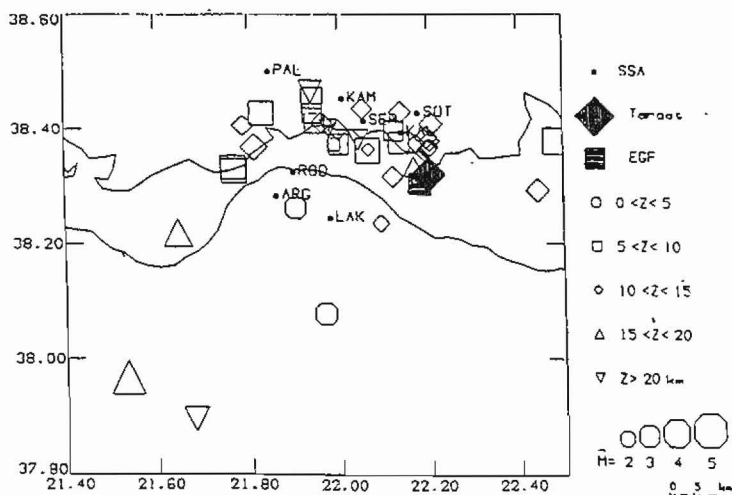


Fig.4. Strong motion network-SSA data (July 1991-September 1992).

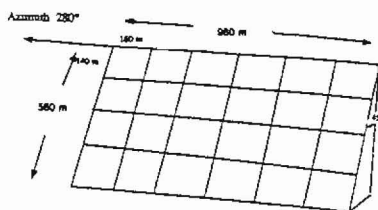


Fig.5. Source model used in all simulations.

geometry of the fault assuming that the length is almost the double of its width. The total number of summations has been estimated by the ratio of their seismic moments calculated from empirical relations, (Tselentis et al., 1988; Kiratzi et al., 1985). The same focal mechanism is assumed for both events, (normal fault, dip 45° and strike 280°), where the locations of their hypocenters (fig.6), propose that they come from the same fault. For the rise time of the small event the value of 0.011 sec has been adopted and it is 4 times smaller than the target's rise time. A sensitivity study of the value of the rise time of the small event has been done, (keeping the same focal mechanisms), that verifies the selection of the value, (fig.7). So the total number of summations are $6 \times 4 \times 4 = 96$.

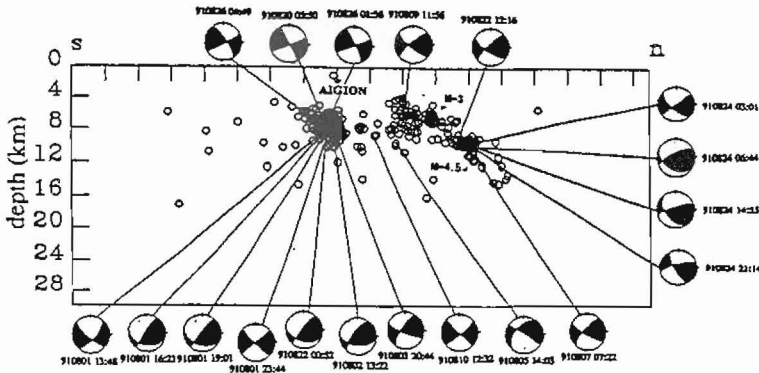


Fig.6. Cross section across the line shown in Figure 3 (Rigo,A., et al., 1992).

Sensitivity studies of the direction of the strike have been done (keeping constants all the other parameters as well as the initialisation point), showing that the correlation of the synthetic and the observed is high within a range of 50 degrees around the direction of the fault proposed by the seismotectonic results. In Figure 8 there is an example using the E-W components of station Sergoula, while similar patterns have been derived from the E-W and N-S components of stations Kallithea and Sotena . There are also two other peaks that correspond to directions perpendicular to the fault direction. The S-wave velocity in the depth of the fault, $v_s = 3.5$ km/sec, has been chosen as the appropriate velocity for v_s travel time corrections. The rupture propagates with a constant velocity $v_r = 0.75v_s = 2.6$ km/sec in all directions so that the rupture front is circular.

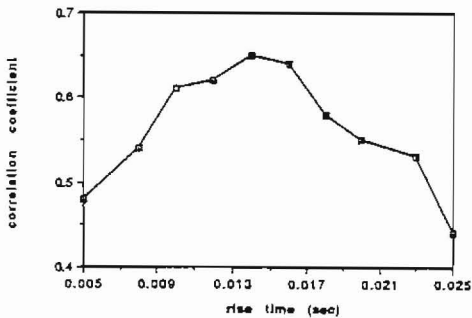


Fig.7. Correlation coefficient versus the rise time of the small event.

In Figure (9) there are some examples of the simulation in different stations. There is a good agreement in the waveforms between the synthesized and the observed ones. In the spectrum there is a good fit in low and high frequencies, but there is an obvious overestimation of the spectrum in the very low

frequencies that is probably caused to the digitisation noise and the dynamic limitations of the accelerographs for recording small earthquakes. For this range of frequencies it is impossible to test the validity of the method with so small events that their energy is distributed in higher frequencies.

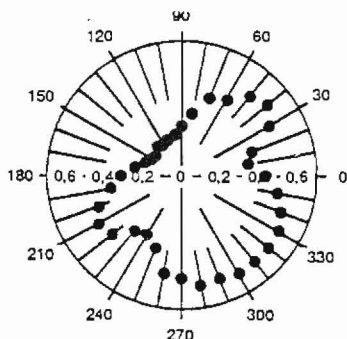
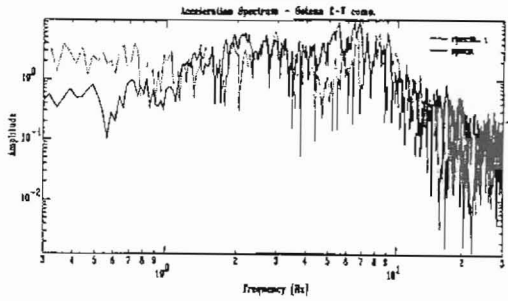
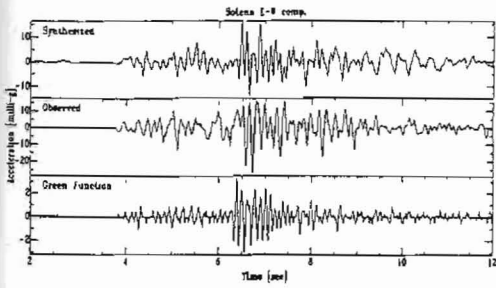


Fig.8. Correlation coefficient versus fault's strike.

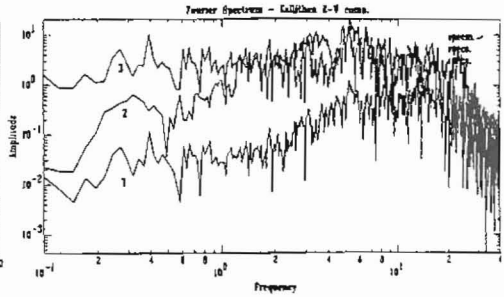
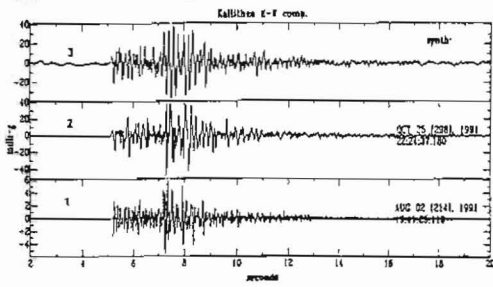
WAVEFORM SPATIAL VARIATION

The validity test of this method should not only be concentrated in the comparison between the synthetics and the observed waveforms. In order to have the right to use this method for the prediction of the strong ground motion for the evaluation of the seismic hazard of a region, the spatial variation of the waveforms must be studied. If there is a big difference in the waveforms between the small earthquakes, the simulations can have large variations. Thus, the waveforms of 25 events (no 1 to 25) having magnitudes between 2 and 3 that belong to a swarm located near the two events that have been used for the simulations, as well as 5 events (no 30 to 34) located a few kilometres nearby, have been tested, (fig. 10). Every event has been recorded in at least three or four stations. Therefore, 120 velocity traces having hypocentral distances ranging from 10 to 37 km have been compared. The focal mechanisms are known for the 9 events of the swarm (no 14, 16, 18, 19, 20, 21, 23, 25, 26) and for all the other five events. Apart from two events of the swarm (no 14 and 26), the focal mechanisms are almost the same. The traces have been filtered with a lowpass filter of 10 Hz, in order to eliminate the differences in high frequencies caused by the difference of the magnitudes. The intercorrelations among all the traces for every station and component, have been systematically calculated. The maximum correlation peaks reveal a very good similarity in the waveforms of the swarm as well as some differences (fig.11 A-B). The events with almost the same focal mechanism (no 16, 18, 19, 20, 21, 23, 25) have the best correlations ranging between 0.6 and 0.9. The first of the two earthquakes with the different mechanism (no 14, fig.11-C), gives correlations with a big



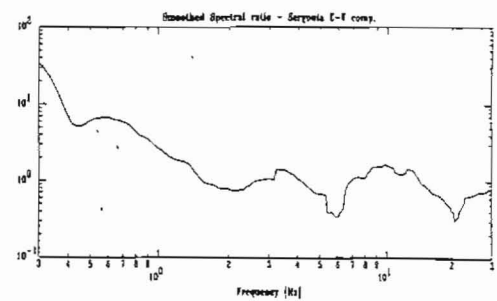
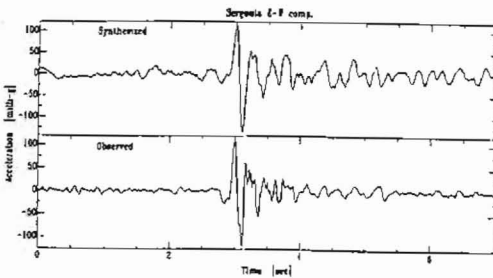
Comparison of the waveforms as well as of the acceleration spectrums at Sotena station.

(With dotted line is the spectrum of the synthetic)



Comparison of the waveforms as well as of the acceleration spectrums at Kallithea station.

(1=Green function, 2=Observed and 3=Synthesized)



Comparison of the waveforms as well as of the smoothed spectral ratio at Sergoula station.

Fig.9. Simulation examples of the three stations.

scattering (0.3 to 0.8). On the other hand the second gives generally very good correlations (fig. 11-B). Despite of the similar focal mechanisms, the intercorrelations among the events of the swarm and the others are generally bad around 0.3, (fig. 11-D), but the differences in distance must be considered. There is no similarity among the traces recorded in different stations showing the strong influence of the site and path effect in the small earthquakes.

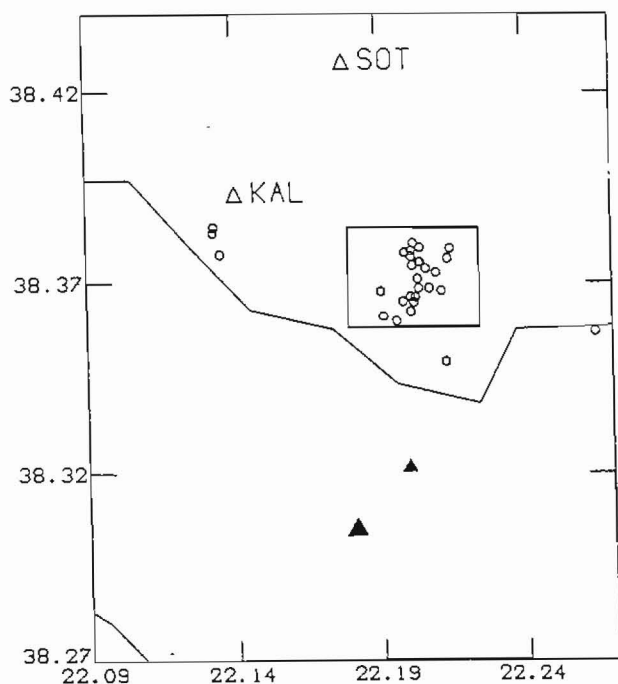


Fig.10. Events used in this study; The triangles are the positions of the 4.5 and 3 that were used for the simulation; There is also the swarm and the 5 others. The three earthquakes near Kallithea station have numbers 31,33 and 34.

CONCLUSION

The first results of the validity test of the empirical Green's function method in Greece are encouraging. The acceleration spectrum, the peak ground acceleration, the corner frequency as well as the waveform of the simulations are in good agreement with those of the observed earthquakes. More tests must be done in larger earthquakes where the spatial variation of the empirical Green's functions is more important. The importance of this method is the exploitation of the path and site information that exists in the recordings of the small earthquakes, that are

not rare in Greece, in order to predict the characteristics of a future large earthquake.

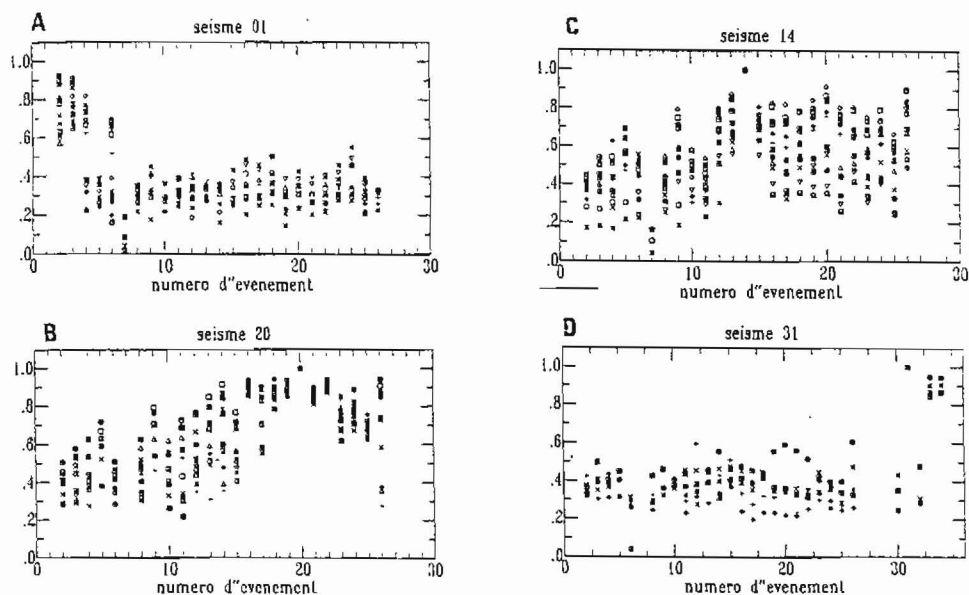


Fig.11. Waveform correlation coefficient for events 1,20,14,31 versus all the events from the swarm.

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REFERENCES

- Aki,K., 1967. Scaling Law of Seismic Spectrum, *Journal of Geophysical Research*, 72, 1217-1231.
- Aki,K., 1979. Characterization of Barriers on an Earthquake Fault, *Journal of Geophysical Research*, 84, 6140-6148.
- Aki,K., 1984. Asperities, Barriers, Characteristic Earthquakes and Strong Motion Prediction, *Journal of Geophysical Research*, 89, 5867-5872.
- Alessandrini,B., Rovelli,A., Cocco,M., Mazza,S., 1990. Computation of Ground Displacement from Strong-Motion Accelerograms Using the Exact Deconvolution Technique, *Bull. Seis. Soc. Am.*, 80, 1753-1761.
- Boatwright,J., 1988. The Seismic Radiation from Composite Models of Faulting, *Bull. Seis.Soc. Am.* Vol.78, 489-508.
- Brooks,M. and Ferentinos, 1984. Tectonics and sedimentation in the gulf of Corinth and the Zakynthos and Kefallinia channels, western Greece, *Tectonophysics*, 101:25-54.

- Dan, K., Watanabe, T., Tanaka, T., Sato, R., 1990. Stability of earthquake ground motion synthesized by using different small-event records as empirical Green's functions, *Bull. Seis. Soc. Am.*, 80, 1433-1455.
- Das, S., Aki, K., 1977. Fault Plane with barriers: A versatile earthquake model, *Journal of Geophysical Research*, 82, 5658-5670.
- Gariel, J.C., Mohammadioun, B., 1991. Simulation des mouvements forts par la technique des fonctions de Green Empiriques, *Note Technique SERGD/91/41*.
- Geller, R., 1976. Scaling relations for earthquake source parameters and magnitudes, *Bull. Seis. Soc. Am.*, 66, 1501-1523.
- Hartzell, Stephen H., 1978. Earthquake aftershocks as Green's functions, *Geophysical Research Letters*, 5, 1, pp. 1-4.
- Haskell, N.A., 1964. Total energy and energy spectral density of elastic wave radiation from propagating faults, *Bull. Seis. Soc. Am.*, 54, 1811-1841.
- Houston, H. and Kanamori, H., 1986. Source spectra of great earthquakes: teleseismic constraints on rupture processes and strong motion, *Bull. Seism. Soc. Am.*, 76, 19-42.
- Irikura, K., 1983. Semi-empirical estimation of strong ground motions during large earth-quakes, *Bull. Disas. Prev. Res. Institute, Kyoto University*, 33, Part 2, N 298, 63-104.
- Irikura, K. and Aki, K., 1988. A procedure for synthesizing strong ground motion from large earthquakes using small earthquake records, submitted to *Bull. Seism. Soc. Am.*
- Irikura, K., 1986. Prediction of strong acceleration motions using empirical Green's function, *Proc. Seventh Jap. Earth. Eng. Symp.*, 151-156.
- Irikura, K., 1988. Estimation of near-field ground motion using empirical Green's function, *Proceedings of the 9th World Conference of Earthquake Engineering*, 8, 37-42.
- Irikura, K., Review on Strong Ground Motion Prediction in Japan.
- Irikura, K., The Physical Basis of the Empirical Green's Function Method and the Prediction of Strong Ground Motion for Large Earthquake.
- Joyner, W.B. and Boore, D.M., 1986. On simulating large earthquakes by Green's function addition of small earthquakes, in *Earthquake Source Mechanics*, *Geophysical Monograph 37* (Maurice Ewing series 6), S. Das, J. Boatwright and C.H. Scholz, Editors, American Geophysical Union, Washington D.C., 269-274.
- Kanamori, H., 1979. A semi-empirical approach to prediction of long-period ground motions from great earthquakes, *Bull. Seis. Soc. Am.*, 69, 1645-1670.
- Kanamori, H. and Anderson D.L., 1975. Theoretical basis of some empirical relations in seismology, *Bull. Seis. Soc. Am.*, 65, 1073-1095.
- Kiratzis, A.A., Karakaisis, G.F., Papadimitriou, E.E. and Papazachos, B.C., 1985. Seismic source-parameter relations for earthquakes in Greece, *PAGEOPH*, 123, 27-41.
- Kiratzis, A.A. and Papazachos, B.C., 1984. Magnitude scales for earthquakes in Greece, *Bull. Seis. Soc. Am. Vol. 74, No 3*, pp 969-985.
- Rigo, A., Lyon-Caen, H., Armijo, R., Bernard, P., Makropoulos, K.,

- Papadimitriou, P. and Deschamps, A., 1992. Deformation studies in the western part of the gulf of Corinth, American Geophysical Union.
- Spudich, P. and Miller, D.P., 1990. Seismic site effects and the spatial interpolation of earthquake seismograms: Results using aftershocks of the 1986 North Palm Springs, California, earthquake, Bull. Seis. Soc. Am., 80, 1504-1532.
- Takemura, M. and Ikeura, T., 1989. J. Phys. Earth, 36, 89-106.
- Tselentis G.-A., Stavrakakis G., Makropoulos, K., Latousakis, J. and Drakopoulos, J. 1988. Seismic moments of earthquakes at the western Hellenic arc and their application to the seismic hazard of the area, Tectonophysics, 148, 73-78.
- Wennerberg, L., 1990. Stochastic summation of empirical Green's functions, Bul. Seis. Soc. Am., 80, 1418-1432.
- Wu, F.T., Song, L.Y. and Wang, P.D., 1984. A ground motion synthesis study using small earthquakes as Green's functions, paper presented at International Workshop on Earthquake Engineering, Natl. Sci. Found., Shanghai.