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A Strong Motion Database in Greece

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Abstract. The increasing of the strong motion records not only in Greece but everywhere in the world and the need for the data and the information to be dispersed forced the Geodynamic Institute of the National Observatory of Athens to develop a friendly-to-user database, which includes all the available information about the records (plots, peak values etc.), the stations (coordinates, installation building, geology, orientation etc.) and the earthquakes (origin time, coordinates, magnitude, maximum intensity). A brief history of the Greek national strong motion network development together with some statistical information, a brief description of the strong motion record processing procedure, the main characteristics of this strong motion database and some simple instructions for its use are described in this study.

Key words: strong ground motion, database, Greece.

1. Introduction

The Geodynamic Institute of the National Observatory of Athens (N.O.A.) has been operating a permanent strong motion network since 1973. The main points of the history of this network are its deployment in 1972 by the installation of 15 analog SMA-1 type accelerographs – the first ever used in Greece – the increase of the installed instruments to 40 in 1986 and the gradual use of digital instruments of A-800 type since 1995. A schedule of increasing the number of installed instruments to 70, replacing at the same time the majority of analog instruments with digital ones is in progress. The map of Figure 1 shows the location of the strong motion stations by the end of 1999. Solid circles represent the SMA-1 instruments, solid squares are for the A-800 instruments, while solid asterisks stand for the local arrays.

Figure 2 shows the cumulative number of records throughout the period of operation of the strong motion records. Some strong earthquakes and their aftershock sequences, together with the organizing of the maintenance of the network and the installation of digital instruments replacing the analog ones are the main reasons for the rapidly increasing of the number of records during the last years.

In 1992 a volume was published including the processed accelerograms recorded from the N.O.A.'s permanent network for the period 1973–1990 (Stavrakakis *et al.*, 1992). This was the first work of this kind in Greece and it was also the

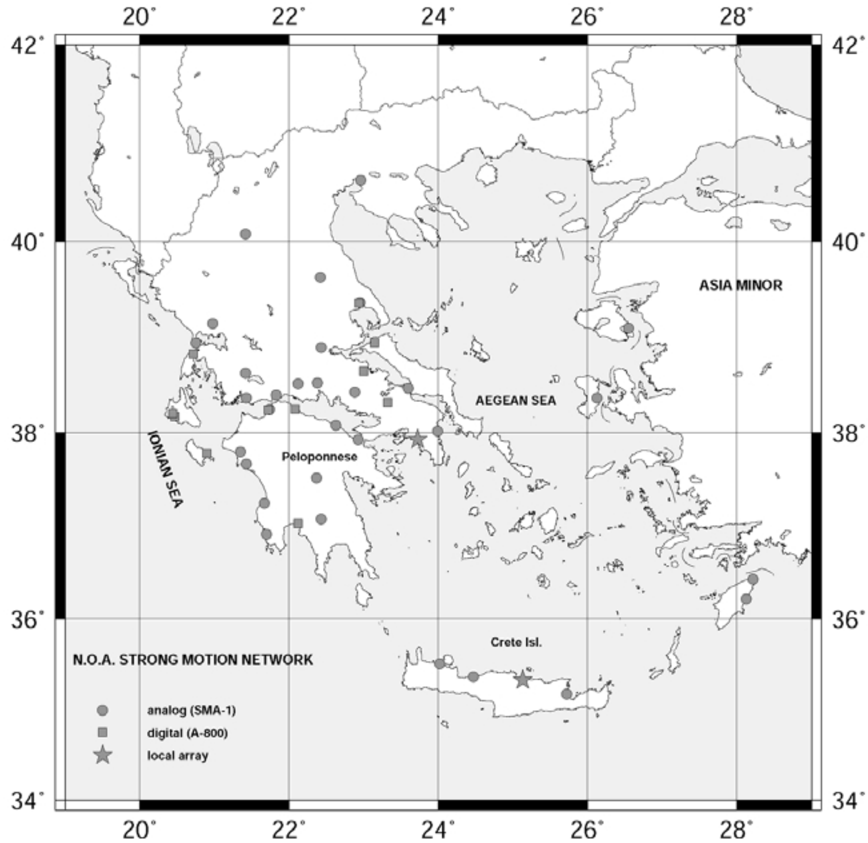

Figure 1. The spatial distribution of the permanent strong motion stations of the National Observatory of Athens (present situation).

first time that a Greek Institution released the processed data in digital and printed format. This work was followed by another two similar publications (Kalogeras and Stavrakakis, 1995, 1998) covering the time periods 1990–1994 and 1994–1996. A selection of the recorded earthquakes, which fill at least one of the criteria of magnitude (Ms $\geqslant$ 5.5) or of the peak ground acceleration (ag $\geqslant$ 0.05 g), is included in Table I. The map of Figure 3 shows the spatial distribution of the earthquakes recorded and included in the described database.

The same format for the processed strong motion data was also followed for the cases of destructive earthquakes (Kalogeras and Stavrakakis, 1996, 1999), when it is important for the data to be released as soon as possible.

A similar work of presenting the strong motion records was done only in 1997 by the researchers of the Institute of Engineering Seismology and Earthquake Engineering, an Institution that operates the other permanent strong motion network in Greece (I.T.S.A.K., 1997). The main disadvantage of this work is that

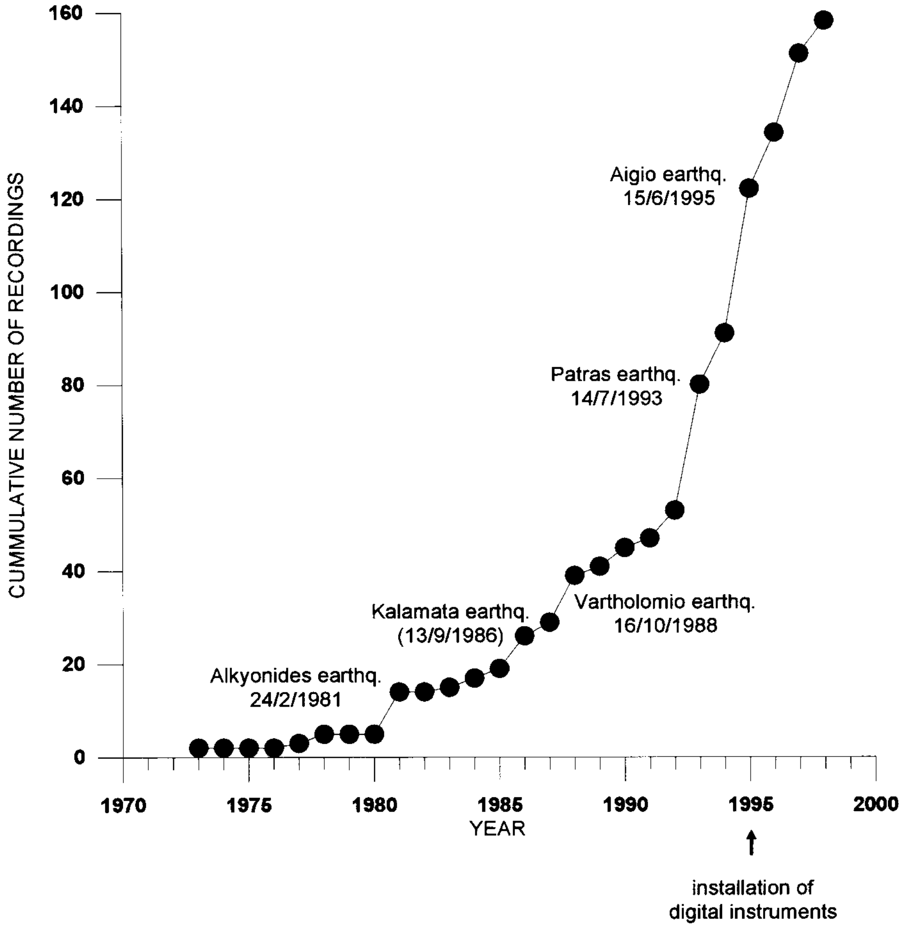

Figure 2. The cumulative number of records throughout the years of the N.O.A.'s strong motion network operation.

the data being processed in three different ways accounts for a difficulty in the homogenization of the data.

The procedure followed by the Geodynamic Institute for the analysis of strong motion records is based on the standard procedure of the CALTECH Institute (Trifunac and Lee, 1973). The procedure was described in detail by Stavrakakis *et al.* (1992) and is organized within three steps. Firstly the analog record is digitized and scaled to units of acceleration and time. Then the data are corrected for the instrument response and baseline adjustment, they are passed through the low and high pass filters and integrated twice to get velocity and displacement data. At this second stage the work of previous investigators about data correction and filter values is being taken into account (Hudson and Brady, 1971; Trifunac and Lee, 1973; Trifunac *et al.*, 1973; Hudson, 1979; Trifunac and Lee, 1979; Basili and Brady, 1978; Carydis *et al.*, 1984; Margaris, 1986; Anagnostopoulos *et al.*, 1986; Carydis

Table I. Information about earthquakes and records fulfilling at least one of the criteria of magnitude (Ms $\geqslant$ 5.5) and of peak ground acceleration (ag $\geqslant$ 0.05 g) for the period 1973–1998

RECORD CODE	DATE	TIME	LAT φ°N	LON λ°E	DIST km	Ms	Imax	LONG ACCEL g	LONG VELOC cm/s	LONG DISPL cm	VERT ACCEL g	VERT VELOC cm/s	VERT DISPL cm	TRAN ACCEL g	TRAN VELOC cm/s	TRAN DISPL cm
LEF4	04/11/1973	15:52	38.90	20.50	20	5.8	VII+	0.515	55.17	12.31	0.122	7.33	1.62	0.258	26.31	6.07
THE1	20/06/1978	20:03	40.80	23.20	28	6.5	VIII+	0.139	12.34	3.70	0.130	6.08	1.43	0.143	16.29	4.03
KOR2	24/02/1981	20:54	38.20	23.00	31	6.7	IX	0.234	23.86	6.03	0.108	9.93	3.67	0.299	32.26	9.70
XLC2	24/02/1981	20:54	38.20	23.00	35	6.7	IX	0.290	26.26	9.43	0.190	25.91	8.10	0.114	7.99	2.43
ATH1	24/02/1981	20:54	38.20	23.00	69	6.7	IX	0.221	25.96	5.89	0.057	6.01	3.39	0.096	11.80	4.24
KOR3	25/02/1981	02:36	38.20	23.10	33	6.4	VIII	0.117	12.20	4.14	0.044	5.13	1.90	0.121	13.09	5.66
PRE1	10/03/1981	15:16	39.30	20.80	39	5.8	VII+	0.141	9.38	1.64	0.080	3.28	0.95	0.137	10.75	2.73
LEF5	10/03/1981	15:16	39.30	20.80	53	5.8	VII+	0.057	3.31	0.29	0.023	1.87	0.27	0.097	4.65	0.46
LEF8	27/05/1981	15:04	38.80	20.70	3	5.5	-	0.117	4.70	0.37	0.047	1.09	0.12	0.093	4.17	0.22
HER1	19/03/1983	21:42	35.35	25.32	38	5.7	V+	0.079	3.72	0.24	0.064	1.48	0.11	0.171	6.23	0.30
KAL1	13/09/1986	17:25	37.10	22.19	10	6.0	X	0.217	32.81	7.33	0.328	15.56	2.36	0.291	32.13	6.81
ROD1	05/10/1987	09:27	36.29	28.46	27	5.6	VI+	0.056	2.21	0.19	0.022	0.74	0.12	0.052	2.63	0.24
ARG1	05/10/1987	09:27	36.29	28.46	31	5.6	VI+	0.031	1.34	0.19	*	*	*	0.046	1.75	0.14
VLS1	18/05/1988	05:18	38.35	20.47	23	5.8	VI	0.165	6.08	0.74	0.074	4.48	0.87	0.174	8.72	1.84
VLS2	22/05/1988	03:44	38.35	20.54	21	5.5	VI	0.053	1.71	0.14	0.034	1.53	0.20	0.079	2.45	0.29
AMA7	22/09/1988	12:06	37.99	21.11	30	5.5	VI	0.021	0.86	0.14	0.015	0.55	0.11	0.018	0.97	0.12
AMA6	16/10/1988	12:32	37.90	20.96	36	6.0	VIII	0.082	4.28	0.41	0.046	1.93	0.15	0.155	9.84	1.04
PRE3	16/06/1990	02:16	39.13	20.38	38	6.0	-	0.033	2.90	0.58	0.015	1.35	0.35	0.034	3.12	0.45
MRN1	18/11/1992	21:11	38.26	22.37	36	5.7	VI	0.019	1.10	0.17	0.015	1.05	0.18	0.020	1.08	0.14
MRN2	18/11/1992	21:11	38.26	22.37	36	5.7	VI	0.090	4.63	0.48	0.036	2.04	0.22	0.075	5.42	0.64
AMF1	18/11/1992	21:11	38.26	22.37	30	5.7	VI	0.056	2.50	0.25	0.029	1.11	0.12	0.101	3.87	0.29
AIG11	18/11/1992	21:11	38.26	22.37	25	5.7	VI	0.039	1.23	0.14	0.025	.70	0.15	0.030	1.43	0.19
KYP1	05/03/1993	06:55	37.07	21.46	27	5.8	V	0.028	1.14	0.09	0.017	0.78	0.10	0.027	0.52	0.06
AMA12	26/03/1993	11:58	37.65	21.44	18	5.5	VI	0.112	4.72	0.39	0.053	1.29	0.12	0.086	4.18	0.49

Table I. Continued

RECORD CODE	DATE	TIME	LAT φ°N	LON λ°E	DIST km	Ms	Imax	LONG ACCEL g	LONG VELOC cm/s	LONG DISPL cm	VERT ACCEL g	VERT VELOC cm/s	VERT DISPL cm	TRAN ACCEL g	TRAN VELOC cm/s	TRAN DISPL cm
PRE4	13/06/1993	23:27	39.25	20.57	37	5.9	VI	0.017	1.67	0.24	0.009	0.79	0.11	0.012	1.15	0.15
LEF9	13/06/1993	23:27	39.25	21.12	48	5.9	VI	0.135	7.35	0.50	0.085	2.34	0.07	0.047	2.21	0.18
AIG12	14/07/1993	12:32	38.16	21.76	30	5.6	VII	0.034	1.26	0.15	0.029	1.10	0.20	0.051	2.20	0.24
PAT11	14/07/1993	12:32	38.16	21.76	10	5.6	VII	0.116	6.41	1.03	0.070	3.42	0.29	0.186	10.95	0.82
AMA19	14/07/1993	12:32	38.16	21.76	54	5.6	VII	0.019	0.68	0.09	0.012	0.47	0.06	0.027	1.10	0.10
MSL1	14/07/1993	12:32	38.16	21.76	37	5.6	VII	0.033	2.04	0.27	0.021	1.02	0.17	0.031	1.89	0.24
NAU2	14/07/1993	12:32	38.16	21.44	27	5.6	VII	0.038	2.57	0.25	0.038	2.39	0.16	0.050	3.92	0.34
LEF10	25/02/1994	02:31	38.73	20.58	16	5.8	V+	0.171	13.40	1.93	0.059	5.23	1.53	0.197	13.40	1.44
PRE5	25/02/1994	02:31	38.73	20.58	29	5.8	V+	0.032	3.40	1.45	0.018	2.55	1.47	0.033	3.40	1.46
CHN1	23/05/1994	06:46	35.40	24.73	66	6.1	VI	0.037	2.96	0.64	0.017	2.02	0.48	0.058	4.45	0.67
RTH2	23/05/1994	06:46	35.40	24.73	24	6.1	VI	0.050	2.32	0.43	0.023	1.36	0.26	0.037	2.44	0.86
AIG14	15/06/1995	00:16	38.37	22.15	15	6.6	VII	0.492	44.04	6.64	0.193	14.21	1.58	0.533	46.30	5.05
AMF2	15/06/1995	00:16	38.37	22.15	27	6.6	V+	0.121	7.79	0.81	0.066	2.20	0.22	0.183	9.40	0.58
KOR5	15/06/1995	00:16	38.37	22.15	84	6.6	IV	0.014	1.37	0.31	0.018	1.77	0.30	0.007	0.44	0.04
LEV1	15/06/1995	00:16	38.37	22.15	64	6.6	-	0.028	2.02	0.28	0.026	1.97	0.20	0.024	1.76	0.17
MRN3	15/06/1995	00:16	38.37	22.15	26	6.6	V	0.069	3.59	0.37	0.043	2.67	0.47	0.073	3.34	0.62
NAU7	15/06/1995	00:16	38.37	22.15	28	6.6	IV+	0.037	3.22	0.42	0.029	1.87	0.22	0.046	3.16	0.60
PAT16	15/06/1995	00:16	38.37	22.15	38	6.6	V	0.033	6.93	3.31	0.020	3.20	1.56	0.041	7.68	3.28
AIG15	15/06/1995	00:31	38.30	22.03	7	6.2	-	0.050	3.65	0.36	0.036	1.34	0.17	0.068	4.69	0.40
AMF3	15/06/1995	00:31	38.30	22.03	40	6.2	-	0.019	0.76	0.06	0.014	0.62	0.04	0.011	0.50	0.04
MRN4	15/06/1995	00:31	38.30	22.03	26	6.2	-	0.019	0.74	0.09	0.011	0.71	0.17	0.018	1.01	0.10
PAT17	15/06/1995	00:31	38.30	22.03	26	6.2	-	0.013	1.20	0.39	0.006	0.48	0.21	0.011	0.79	0.32
SPA3	13/10/1997	13:40	36.41	22.18	78	6.1	VI+	0.023	4.54	1.26	0.017	4.49	1.31	0.033	5.46	1.54
AMA23	18/11/1997	13:08	37.26	20.49	97	6.6	VI+	0.040	4.54	2.08	0.026	1.19	0.18	0.036	3.78	0.57
KYP3	18/11/1997	13:08	37.26	20.49	105	6.6	VI+	0.017	2.06	1.00	0.008	0.52	0.08	0.015	0.86	0.11

Table I. Continued

RECORD CODE	DATE	TIME	LAT φ°N	LON λ°E	DIST km	Ms	Imax	LONG ACCEL g	LONG VELOC cm/s	LONG DISPL cm	VERT ACCEL g	VERT VELOC cm/s	VERT DISPL cm	TRAN ACCEL g	TRAN VELOC cm/s	TRAN DISPL cm
PRG3	18/11/1997	13:08	37.26	20.49	95	6.6	VI+	0.038	3.09	0.46	0.024	1.38	0.14	*	*	*
LXR15	18/11/1997	13:08	37.26	20.49	104	6.6	VI+	0.018	0.88	0.07	0.009	0.41	0.04	0.020	1.09	0.10
PRG4	18/11/1997	13:14	37.36	20.65	77	6.1	-	0.015	0.86	0.07	0.010	0.54	0.07	0.010	0.74	0.07
LEF17	16/07/1998	17:29	38.66	20.56	23	5.6	–	0.010	0.92	0.16	0.007	0.47	0.08	0.015	1.51	0.27
ZAK3	08/10/1998	03:50	37.79	20.27	55	5.7	–	0.075	2.74	0.18	0.024	0.66	0.03	0.045	1.31	0.14

*Component not triggered due to technical problem.

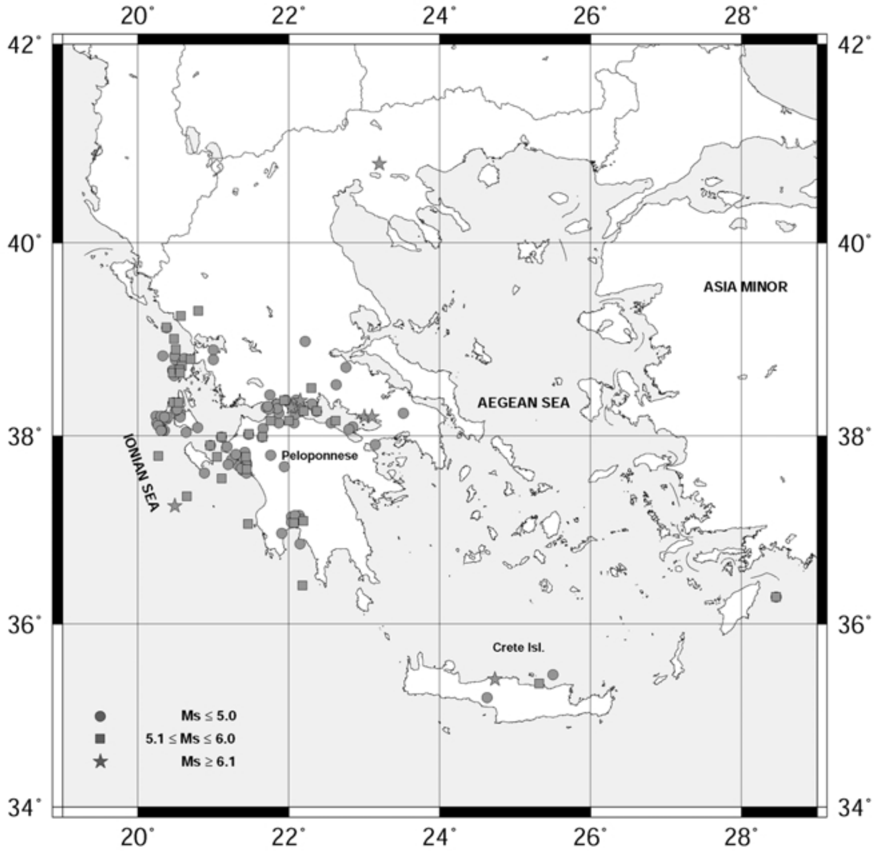

Figure 3. Spatial distribution of the earthquakes recorded by the permanent strong motion network of National Observatory of Athens.

et al., 1989; Lekidis *et al.*, 1991), while the modification of Shakal and Ragsdale (1984) concerning the re-sampling and the selection of the low cutoff frequency are adopted. Finally the response spectra and the Fourier amplitude spectra are calculated.

In Figure 4, two bar diagrams are shown referring to the relation between the magnitude and the number of records (the upper one) and between the epicentral distance and the number of records (the lower one).

As far as the processing of the digital records is concerned a simple computer program is used aiming to change the format of the ASCII record files so that they can be manipulated by the fore-mentioned software. The advantage of this is that, although the instruments come from different manufacturers, the results can be taken as homogenized.

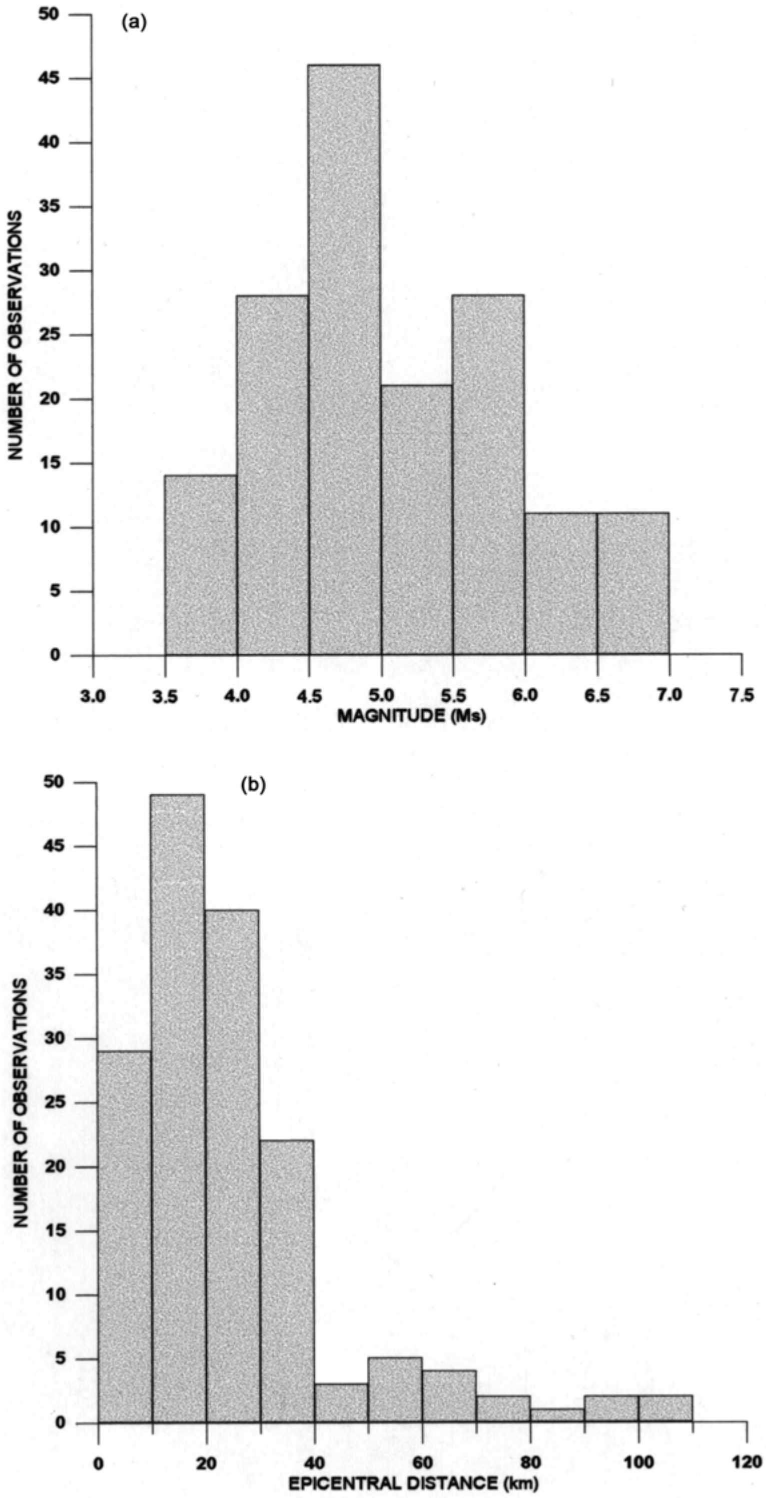

Figure 4. Bar diagrams showing the relation between the magnitude and the number of records (a) and between the epicentral distance and the number of earthquakes (b).

2. Construction and Structure of the Database

The present database exists for the release and exchange of strong motion data with other Institutions in Greece and elsewhere and to become the basis of co-operative research projects in seismology and earthquake engineering.

Care has been taken for the records to be accompanied by other critical or useful information concerning the station, the instrument characteristics and the earthquake parameters. The processing procedure has been done in a uniform format for the analog and digital data.

The database is constructed under MsAccess, a widely used software package (Prague and Irwin, 1997). Moreover, MsPaint and WordPad should be installed in the user's computer in order to view or maintain the graphic and the ASCII files included in the database. The use of the database requires a lot of memory, so a RAM of at least 32MB is preferable.

The Tables and the Forms are the basic parts of the database, while Queries are used to isolate records due to specific criteria. The Tables are used in order to introduce all the available information into the database. The Forms are used in order to present this information in a more suitable way. Moreover different help-files are included within the database.

Figure 5 shows the structure of the database. In its first version it includes more than 150 uncorrected and corrected 3-component strong motion records that cover the period 1973–1998. Although every effort has been done in order to include as much information as possible, some blank spaces exist, which will be filled during following versions, together with the new data, which will be added in a stable basis. The user should note that the data recorded from the N.O.A's permanent strong motion network are included in the database, whatever the magnitude, the epicentral distance or the peak ground values. It's upon the user's will and the type of research specific records to be isolated. Nevertheless, the good quality of the original record (especially speaking for analog records) is the basis of the whole procedure.

2.1. TABLES

Four main independent Tables are constructed including different information:

Table 'Data' includes the earthquake parameters, the record codes, the epicentral and the intensity maps, and the peak values of acceleration, velocity and displacement for the three components of each record.

Table 'Stations' includes the information about each station of the N.O.A.'s permanent strong motion network, such as the site name, the coordinates, the type and the photo of the building, the geology of the site and various notes concerning each station.

Table 'V1plots' includes the plot and ASCII files of the uncorrected data of the three components of each record.

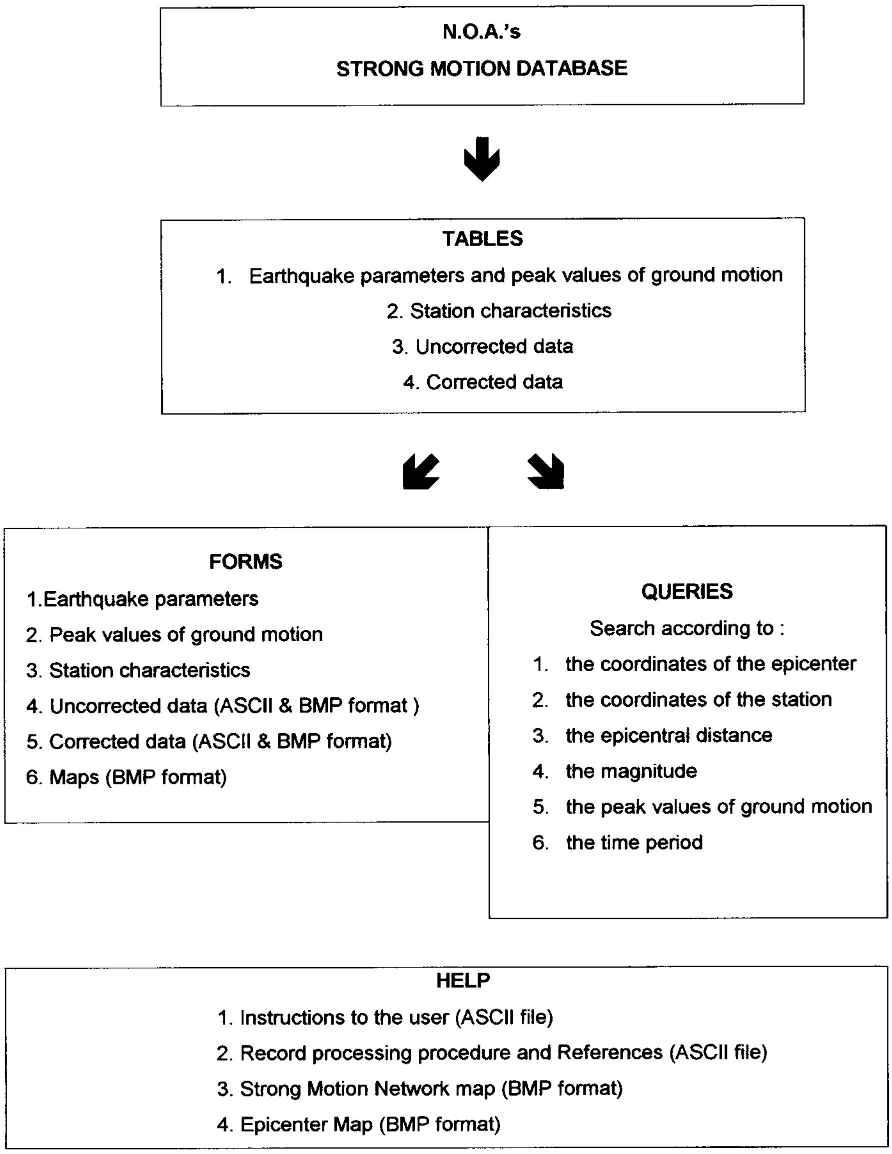

Figure 5. The structure of the strong motion database.

Table 'V2plots' includes the plot and ASCII files of the corrected (following the above mentioned procedure) time histories of acceleration, velocity and displacement for the three components of each record.

The format of the uncorrected and corrected plots and ASCII files follows the V1 and V2 format respectively (Trifunac and Lee, 1973).

2.2. FORMS

The information introduced into the Tables is then represented within the Forms.

The 'Data' form is the main form to the whole database. Through this form and with the help of keys the user is led to all the information. Each screen of the 'Data' form has been divided in three parts. The record code, the recording site, the date and the origin time of the earthquake are shown on the top. The peak corrected values of acceleration, velocity and displacement for each component are shown at the main part of the screen. A menu exists on the left of the screen consisting of the following keys: Key 'Help' leads to two help files, one with instructions concerning the use of the database, and the other describing the strong motion record processing procedure followed in the Geodynamic Institute.

Key 'Show All Data' leads to the Table 'Data'.

Keys 'Station Data' and 'Earthquake Data' open the forms including information about the station and the earthquake respectively. From the screen of the 'Station Data' form the user can have the photograph of the building where the instrument is installed. From the screen of the 'Earthquake Data' form the user can view the intensity map of the earthquake, if such data exist.

Key 'Map' opens the map showing the sites of the station and the epicenter.

Key 'Uncorrected Data Plots' opens the uncorrected acceleration traces as they have been digitized and plotted. An option exists for viewing and printing the ASCII files of these plots.

Key 'Corrected Data Plots' opens the corrected acceleration, velocity and displacement time histories, as they have been plotted after the interpolation, the baseline correction and the filtering of the uncorrected traces. An option also exists for viewing and printing the ASCII files of these plots.

It is important for the user to associate files with extension V1 and V2 with the program WordPad.

2.3. QUERIES

MsAccess offers to the user the opportunity to combine data due to specific criteria concerning the magnitude, the epicenter coordinates, the peak values etc. The user should click the key 'Design' of the appropriate query and then fill up the requested criteria.

3. Outlooks

The increase of the strong motion records leads to the development of large scientific researches in the fields of engineering seismology and earthquake engineering, like attenuation relationships, improvement of design codes, seismic hazard assessment etc. The needs of dispersion of information as well as the possibility of comparative studies using as many recordings as possible, led the scientists to develop and use databases that include all the available information about the earthquakes, the recording stations and the strong motion records. However, difficulties such as the limited number of databases (until now), inaccessibility to the broad scientific community, different formats of presentation, absence of crucial or less important information, together with the records themselves should be overcome.

As the Geodynamic Institute is the authoritative institution in Greece for informing the government and the public about the earthquakes, the release of the data in a user-friendly way became a necessity. Thus, the development of a strong motion database aims in this direction. The advantages of this database are that it runs under a widely-known software, such as MsAccess, it is flexible – which means that the user can add his own data in a simple way – and, finally, its development philosophy can be used to present separately the strong motion data of an aftershock sequence. As an example of the latter, the case of the destructive earthquake of Athens in September 1999 can be referred, when 64 3-component strong motion records were processed and their results (peak values, plots, ASCII files, response spectra), together with the earthquake parameters, the station information and a preliminary intensity map were all included in a user-friendly database, released only two months after the earthquake (Kalogeras and Stavrakakis, 1999)

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The field-work of the technicians of the Geodynamic Institute is crucial for the maintenance of the strong motion network and is appreciated. The maps of Figures 1 and 3 were made by using the GMT software provided by P. Wessel and W. H. F. Smith. Constructive comments and helpful suggestions by two anonymous reviewers greatly improved the manuscript.

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