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Manual of M8 Program & Exercise

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User Manual for M8 Program

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1. Introduction

Earthquake prediction is an uncertain profession. Following the Good Friday Alaskan earthquake a panel, called by the U. S. president's science advisor, recommended a ten year program of research on earthquake prediction (*1*). Stimulated by this recommendation the U. S. Geological Survey began a major program of research in 1966. Large research programs on earthquake prediction were undertaken by Japan, China and the Soviet Union at about the same time. After almost thirty years of serious research we have not found a reliable method to predict the time of strong earthquakes.

Many methods for earthquake prediction have been proposed and some of these methods may be reliable. The problem is that most of these methods cannot be adequately tested and evaluated in a lieu of their precise definition and/or in a shortage of statistics.

Mathematicians and geophysicists at the International Institute for Earthquake Prediction Theory and Mathematical Geophysics in Moscow have applied methods of pattern recognition to the problem of earthquake prediction (*2*). V. I. Keilis-Borok and V. G. Kossobokov developed an algorithm, M8, which has successfully predicted several strong earthquakes (*3*). Earthquake predictions from this algorithm have been presented to the U. S. National Earthquake Prediction Evaluation Council, NEPEC (*4*), and NEPEC has recommended that the USGS undertake an evaluation of this algorithm. After successful prediction of the Loma Prieta 1989 earthquake J. H. Healy, V. G. Kossobokov, and J. W. Dewey (*5*) have designed a rigid test to evaluate the earthquake prediction algorithm, M8. Since 1991 each half-year the algorithm is applied in a real time prediction mode to seismicity of the entire Circum Pacific seismic belt. The experiment is set to predict magnitude 7.5+ earthquakes and we expect that in five years there will be more than ten of them in the territory considered.

This publication intends to facilitate communication and better understanding of the intermediate-term earthquake prediction method as it provides ultimate description of the algorithm, i.e. a program with a source code and a set of fixed parameters. M8 is a computer program written in Fortran 77 that permits to make intermediate-term prediction of earthquakes by the M8 algorithm, as well as to evaluate time series of several integral counts based on transient seismicity in a region. These counts might be useful for independent analysis of seismicity.
The first version of M8 program refer to 1986 when the algorithm was reprogrammed for distribution among participants of the Workshop on Earthquake Prediction held in Lima (Peru). Its parent programs were in operation in 1984, when Keilis-Borok and Kossobokov presented the first results related to retroactive prediction of magnitude 8.0+ earthquakes worldwide (*5*). Here we provide the 1991 versions for IBM-compatible personal computers- (PC, XT, AT, 286 PC, 386 PC, 486 PC, 586 PC, PS/1, and PS/2). The version for batch runs is used in updates of the test of M8 algorithm (*6*). Another version permits interactive change. Both versions have the same computational core, and therefore identical output for the same set of input parameters. In 1992 J.-B. Minster and N. P. Williams (*7*) reprogrammed M8 algorithm in C language in a form, which might be more suitable for statistical evaluation. (Final results obtained from their program, M8C, and from M8 may differ due to different roundoff in evaluation of functions.)

The authors have to emphasize that any specific prediction can be made, so far, on experimental basis only, and users are advised to disclaim any liability for consequences of actions based on their predictions. Accordingly the authors disclaim liability for any consequences of the use of this program. Let us remind also that each prediction of a large earthquake has to be released by a qualified scientific body to proper local authorities.

2. M8 Algorithm

The circles of investigation, CI's

The M8 algorithm examines seismicity in circular regions. In early testing of the algorithm on magnitude 8+ earthquakes the best results were obtained with a radius of six degrees. Previous work had established a rough scaling law between magnitude and source dimensions (*8*). After some testing the developers set the relationship between the radius of the CI and the magnitude of the predicted earthquake, M_0, as: $R(M_0) = 55.5 (\exp(M_0-5.6)+1)$; which gives, 668 km for magnitude 8.0, 427 km for 7.5, 281 km for 7.0 and 192 km for 6.5.

Aftershocks

The strongest statistical effect in earthquake catalogs is the phenomenon of aftershocks, the clustering of smaller earthquakes following the occurrence of a larger earthquake. The effect of aftershocks can mask weaker phenomena unless something is done to suppress or remove them. In the M8 algorithm aftershocks are defined as all the smaller earthquakes that follow a larger earthquake within a time and distance that are functions of the magnitude of the mainshock. For purposes of the algorithm the time and distance that define the aftershock zone are arbitrarily set to an exact value in a table from *(9)*:

Magnitude, M	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0+
R(M), km	40	40	50	50	50	100	100	150	200
T(M), days	23	46	91	183	183	365	730	913	1096

All the earthquakes that occur in an "aftershock zone" are removed from the catalog to produce a catalog of "mainshocks". This definition of aftershocks and mainshocks oversimplifies a complicated issue but the definition is adequate for purposes of the algorithm.

Selecting a starting time and magnitude cutoff

Following the methods of pattern recognition the data is transformed by a number of functions. The most important part of these transformations is the averaging over time and space. The spatial averaging is accomplished by selecting all the earthquakes in a given CI. The time averaging is accomplished by summing the values over the preceding *s* years. To count earthquakes we must deal with two important questions: the time interval over which the earthquakes are to be counted and the magnitude of the earthquakes.

The time interval selected for analysis is largely determined by the quality and completeness of the seismic catalogs. In the 1960's the quality and completeness of the global catalogs were improved with installation of the World Wide Seismic Network. Since 1963 all the earthquakes of magnitude five or greater are located and in many areas catalogs are complete to magnitude four. The beginning of the analysis is usually selected as January 1, 1963 although the time may be earlier or later depending on the quality of the local catalogs. It takes about 20 years of data for the algorithm to set the thresholds that define anomalous seismicity, so application of the algorithm is limited to a period of about 10 years in most regions. Some of the functions in the algorithm may not scale with time and some changes in the method of selecting the starting time may be required for regions where there are longer periods of good data and in the future when more decades of good data are available.

To count a number of earthquakes we must choose a magnitude cutoff. In preparation of the data we recommend to set initial cutoff referring to completeness. For example, in the global test of M8 algorithm *(6)* we initially cut the global catalog at magnitude 4.0, because the catalog is seriously incomplete below this threshold.

The M8 algorithm does not choose a fixed magnitude cutoff rather it chooses the number of earthquakes that are desired for the calculation. It selects in each CI two populations of mainshocks. The first one, CAT20, is defined by a magnitude cutoff that yields an average of 20 earthquakes per year. To analyze a 30 year interval the algorithm selects a magnitude cutoff that provides 600 earthquakes. Usually the selected cutoff will yield somewhat more than 600 earthquakes. If there are less than 20 earthquakes per year in the CI we must make a decision to continue or to terminate the analysis. In the test of M8 algorithm *(6)* the analysis is not performed in a CI that contains less than 16 earthquakes per year.

A second population, CAT10, is selected from the CI in the same way using the magnitude cutoff that produces 10 earthquakes per year.

The Functions

The algorithm is based on seven functions of the seismicity data -

$F_1(t)$ is the count of the number of earthquakes from the first population, CAT20, in the preceding six years;

$F_2(t)$ is the same count as $F_1(t)$ for the second population, CAT10;

$F_3(t) = F_1(t) - F'_1(t)$, where $F'_1(t)$ is the average number of earthquakes per six years in the interval from the beginning of the analysis, t_0, to t - 6 years. The measure is taken on CAT20;

$F_4(t)$ is the same as $F_3(t)$ measured on CAT10.

$F_5(t)$ is a magnitude weighted sum of mainshocks divided by the number of these events to the 2/3 power, $10^{0.46Mj}$ /(1)$^{2/3}$. The summations are taken over the preceding six years from a third population, CAT20a = CAT20 - {events with magnitudes Mj above M_0 - 0.5}.

$F_6(t)$ is the same as $F_5(t)$ calculated on a fourth population, CAT10a = CAT10 - {events with Mj above M_0 - 0.5}.

$F_7(t)$ is based on a count of the number of aftershocks. To calculate the function we define a fifth population, CATMS, including mainshocks in the magnitude range (M_0 - 2.0, M_0 - 0.2) within a given CI. The catalog of this population includes the count of aftershocks, B_j, in the first two weeks following each mainshock. $F_7(t)$ is set equal to the largest B_j in CATMS. in the preceding year.

The functions are evaluated every half-year and it is convenient to describe them in terms of half-year intervals ending at $t_i = t_0$ + (i half-years). Let X_i be the number of earthquakes in the half-year interval ending at t_i, and S_i be $10^{0.46Mij}$, where {Mij} are magnitudes of all mainshocks from the i-th half-year interval. In this notation the functions are:

$F_1(t_i) = X_{i-11} + X_{i-10} + ... + X_i$	[CAT20]
$F_2(t_i) = X_{i-11} + X_{i-10} + ... + X_i$	[CAT10]
$F_3(t_i) = F_1(t_i) - (X_1+X_2+...+X_{i-12})\ 12/(i-12)$	[CAT20]
$F_4(t_i) = F_2(t_i) - (X_1+X_2+...+X_{i-12})\ 12/(i-12)$	[CAT10]
$F_5(t_i) = (S_{i-11} + S_{i-10} +...+ S_i)/(X_{i-11} + X_{i-10} +...+ X_i)^{2/3}$	[CAT20a]
$F_6(t_i) = (S_{i-11} + S_{i-10} +...+ S_i)/(X_{i-11} + X_{i-10} +...+ X_i)^{2/3}$	[CAT10a]
$F_7(t_i)$ = max B_j in the preceding year.	[CATMS]

(In square brackets, i.e. [ ], we indicate the catalog used to calculate the function.)

Votes

The functions vote for the declaration of a warning or *time of increased probability*, TIP, for an earthquake with magnitude M_0 in the CI. The first six functions cast their vote for a TIP when they are in the top ten percent of their historic range. The seventh function votes for a TIP when it is in the top 25% of its historic range.

TIP's

A time of increased probability is declared for the CI when five of the first six functions and the seventh function have voted sometime in the preceding three years, and when this condition is met in two successive six-month evaluations. Once a TIP is declared it last for five years from the time of declaration. As new data is added to the catalog the thresholds which cause the functions to vote may change so a TIP may be terminated earlier or extended for more than five years.

M8 program

The ultimate description of the M8 algorithm is M8 program with the set of fixed values of parameters. These are provided as default values in the program. However, the program permits to define and run on seismic catalogs other algorithms based on a general concept of activation. According to this concept predicted phenomena are likely to occur in a system during, or following without much delay, a period of "activation" when the majority of integral measures raise above their normal values. A prediction strategy in this case could be to declare an alarm or *time of increased probability*, TIP, each time when such an "activation" is identified.

The M8 program computes several integral measures on a sequence of earthquakes from an area of investigation and identifies TIP's.

The user must have a catalog of mainshocks in appropriate binary format (see Input for M8 Program).

In one run of M8 program the user has a choice to consider up to 18 areas either of circular or of square shape.

The dimension of areas (i.e. radius or half-side) can be set to a constant value. The user has a choice to set an arbitrary constant or to compute it using above mentioned equation for $R(M_0)$.

The user has a choice to consider up to 9 integral measures of the following types -

(N) count of the number of mainshocks with magnitude M m in the preceding s years,

$$n(t|m,s);$$

(L) deviation of count N from a longer-term average,

$$l(t|m,s,t_0) = n(t|m,s) - n(t|m,t-s-t_0)\ s/(t-s-t_0)\ ,$$

where t_0 is the beginning of the analysis;

(K) difference between two consecutive independent determinations of count N,

k(t|m,*s*) = n(t|m,*s*) - n(t-*s*|m,*s*);

(V) variation of count N in preceding *u* years,

v(t|m,*s*,*u*) = | n(|m,*s*) - n(- |m,*s*) | ,

where   belongs to [t,t-*u*], and   is a uniform step between consecutive determinations;

(S) magnitude weighted sum of mainshocks divided by the number of these events to the power,

s(t|m,M',*s*, ,) = 10^{Mj} /(1) ,

here the summations are taken over the preceding s years on a population of mainshocks with magnitudes Mj, m   Mj < M'. (Note: N-type is formally embedded into S-type for   =   = 0.)

(B) maximal number of aftershocks in the preceding s years,

b(t|m,M',M_a,*s*,*r*) = max B_j ,

here B_j is the number of aftershocks with magnitudes above M_a in the first *r* days following each mainshock, and the maximum is determined over the preceding *s* years on a population of mainshocks with magnitudes Mj, m   Mj < M'. (Note: M8 program does not calculate B_j but uses the counts of aftershocks provided in the catalog of mainshocks. Therefore, the user have to rebuild the catalog of mainshocks to make changes of M_a and/or *r*.)

For each measure, the user has the following options to select either of the two magnitude thresholds, m or M', - an arbitrarily chosen constant (con), a value shifted by constant from M_0 (shf), and a magnitude cutoff that provides, on average in an area of investigation, constant annual number of events (act).

The user have to define the percentile to be used in determination whether a value of a measure is abnormally high or not. The program permits different percentile levels for B-type and other measures. For determination of percentiles (and, if any, magnitude cutoffs defined by constant annual numbers of events) in areas of investigation there is a choice to consider values either from interval (T_b, T_e) or from (T_b, T∗), where T_b is the beginning and T_e is the ending of the analysis, T∗ is a specific time in a given area of investigation. For example, in practice of the M8 algorithm real-time test in Circum Pacific (6) we have chosen intervals (T_b, T∗), with T∗ set to the date half-year before of the update or the origin time of the magnitude M7.5+ earthquake if any predicted in the circle of investigation.

To declare times of increased probability, TIP's, M8 program computes two additional numbers, h(t) and g(t). h(t) counts how many measures were above their normal values sometime in the preceding $_{ex}$ years, while g(t) counts how many different types of measures give positive contribution into h(t). When h(t)   H and g(t)   G at two successive determinations (t -) and t, the program reports of a TIP from t to (t +). (Here , $_{ex}$, H and G are given constants specified by the user.)

M8 program classifies a TIP as

e.c., an "earthquake caused" activation, when an earthquake of magnitude M_0 or above occurred in the same area of investigation during the time from (t - 2) to t, i.e. just before a TIP. The program considers such a case as no alarm;

STIP, a "successful alarm", when an earthquake of magnitude M_0 or above occurred in its spatial and temporal limits;

FTIP, a "false alarm", when it expired before the end of analysis, T_e, and no earthquakes of magnitude M_0 or above occurred in its spatial and temporal limits;

CTIP, a "current alarm", when it is not expired before T_e, and no earthquakes of magnitude M_0 or above occurred in its spatial and temporal limits.

Summing up, M8 program allows the user to investigate seismicity of a region in multidimensional space of integral measures. In such an investigation the user may get far away from the original M8 algorithm, which passed through a number of tests (at least in retroactive applications in numerous regions worldwide), and thus to loose any of its reliability. The user is advised to supplement earthquake prediction results with a number of stability tests described earlier (e.g. retroactive simulation of forward prediction, etc).

3. Hardware Requirements

To run M8 program you need:

(1) An IBM-compatible personal computer (PC, XT, AT, 286 PC, 386 PC, 486 PC, 586 PC, PS/1, and PS/2) running the IBM PC-DOS or MircroSoft MS-DOS operating system (version 3.1 or later).
(2) At least 250 kilobytes of free RAM memory.
(3) A 5.25 or 3.5 inch floppy disk drive.
(4) A hard disk is optional but necessary for any serious work. Floppy disk drives are just too slow and limited in storage capacity. For complete installation of the programs, auxiliary files and data for the M8 algorithm test in Circum Pacific you should have at least three megabytes of free space. At run time, you must have free room to hold output files generated by M8 program.
(5) A math coprocessor (compatible with your PC's CPU) is desirable, but not necessary. Without it floating points calculations will be emulated by software and will slower execution.
(6) A printer if you need to print the results.

4. Software Installation

Although it is possible to run M8 program from a floppy, we will describe the software installation for a hard disk only.

Software installation for M8 program is simply copying the M8 program and its associated files from NLDEP Disk # X. To proceed, first find the NLDEP Disk # X in your binder, and then follow the steps specified below. If you are **not** an experienced PC user, please consult your DOS Manual.

We assume that (1) you have the required hardware specified in Section 3, and (2) your PC boots up on a hard disk (C:), and has a floppy disk drive (A:).

Step 1. Turn on your PC. After the DOS prompt appears on the monitor, go to the root directory by issuing the DOS **cd ** command.

Step 2. Check once again for a free space on your hard disk by issuing the DOS **dir** command.

Step 3. Insert NLDEP Disk # X in the A: drive and perform

a:M8_inst

If your floppy disk drive is B: device in your PC, then substitute b: for a: in the above command.

After installation your PC should have C:\M8 directory with subdirectories M8_EXE, M8_CODE, M8_TEST.

C:\M8\M8_EXE directory should have the following files:

(1) M8.EXE -- Executable program with interactive interface for making counts on sequences of mainshocks and for identification of TIP's in areas of investigation.
(2) M8_BAT.EXE -- Executable program to be run from command line for making counts on sequences of mainshocks and for identification of TIP's in areas of investigation.
(3) ASC2B20.EXE -- Executable program to convert a catalog of mainshocks in an ASCII format to the 20 bytes binary format used by M8 program.
(4) CAT_M8.EXE -- Executable program to select subcatalog of events from specified ranges of latitudes and longitudes out of a given catalog in the 20 bytes binary format.

C:\M8\M8_CODE directory should have the following files:

(1) M8.FOR -- Fortran source code of M8 main program with interactive interface for making counts on sequences of mainshocks and for identification of TIP's in areas of investigation.
(2) M8_BAT.FOR -- Fortran source code of M8 main program to be run from command line for making counts on sequences of mainshocks and for identification of TIP's in areas of investigation.
(3) M8_SUBR.FOR -- Fortran source codes of subroutines for M8 program.
(4) ASC2B20.FOR -- Fortran source code of (3) ASC2B20 program.

(5) CAT_M8.FOR -- Fortran source code of CAT_M8 program.

C:\M8\M8_TEST directory should contain

(1) MS4_NEIC.DAT -- the catalog of mainshocks in 20 bytes binary format (see Manual for CATAL and AFT programs) prepared by P.Shebalin from the National Earthquake Information Center Global Hypocenters Data Base System, and
(2-14) 13 subdirectories with regional "profiles" to run the M8 algorithm test in Circum Pacific as on January 1, 1994 and the results of such a run.
(15) Subdirectory TIMES with the files of dates of the M8 algorithm test updates.
(16) RUN_REG.BAT -- the batch file to run the M8 algorithm test update in a region.
(17) RUN_TEST.BAT -- the batch file to run the M8 algorithm test update in all regions of Circum Pacific.

Each of the 13 subdirectories should have a file of regional boundaries with extension *.CAT, an input profile with extension *.REM (see next Section), and output files from the January 1, 1994 update with extensions *.PRI, *.ERS, *.RES, *.TIP, and *.STR.

The complete contents of these directories are given in the INDEX file of C:\M8 directory.

Step 4. Check the presence of the above files on the hard disk. If these files exist, remove the NLDEP Disk # X from the A: drive and return it to the binder.

5. Input for M8 Program

To run M8 program the user have to specify the following parameters -
(1) Catalog file name. (The catalog file name should not exceed 14 bytes.)You must have a catalog of events in the 20 bytes binary format (a standard for earthquake data analysis used in the International Institute for Earthquake Prediction Theory and Mathematical Geophysics, Russian Academy of Sciences). The description of this format is as follows:

The first 4 bytes of the first record is the total number of records in the file (integer*4), i.e. the number of earthquakes plus 1.

For any of other record:

Position in a record	Contents	Type
1-4	time of the earthquake in minutes AD	integer*4
5-6	latitude*100	integer*2
7-8	longitude*100	integer*2
9-10	depth	integer*2
11-12	magnitude M*100	integer*2
13-14	count of the number of aftershocks, B	integer*2
15-20	reserved	

(2) Magnitude cutoff M_0. This parameter defines events to be predicted as those with magnitude M M_0.

(3) Interval of analysis (T_b, T_e). The dates (year, month, day) of the beginning and ending of determinations of measures, e.g. 1975,1,1,1994,1,1.

(4) Choice of interval for determination of percentiles. Two choices to consider values either: (1) from interval (T_b, T_e) or (2) from (T_b, $T*$), where $T*$ is a specific time in a given area of investigation (e.g. the origin time of a large earthquake).

(5) Increment of determinations . Interval in years, e.g. 0.5.

(6) Number of functions. Total number of counts in one determination, i.e. dimension of description.

(7) Number of areas of investigation. Total number of areas to be considered in a run of the program.

(8) Shape of areas. Two options: circular or squared shape.

(9) Dimension of areas R. Radius of circle or half-side of square in kilometers. If the value of this parameter is set to 0, the program calculates $R = R(M_0) = 55.5 (\exp(M_0-5.6)+1)$.

For each area of investigation the user have to define:

(10) Center of the area. The latitude and the longitude of the center for each area (positive values for N and E, and negative - for S and W).

(11) Time $T*$. The date which is specific for the area.

For each function the user have to define:
(12) Type of measure. One of {n, l, k, v, s, b}.

(13) Type of lower magnitude cutoff. This parameter can be either an arbitrarily chosen constant (con), or a value shifted by constant from M_0 (shf), or a magnitude cutoff that provides, on average, constant annual number of events (act). It is used to specify the lowest limit of magnitude range for the count.

(14) Type of upper magnitude cutoff. This parameter can be either an arbitrarily chosen constant (con), or a value shifted by constant from M_0 (shf), or a magnitude cutoff that provides, on average, constant annual number of events (act). It is used to specify the highest limit of magnitude range for the count.

(15) Value to define lower magnitude cutoff. The value in agreement with the type of magnitude cutoff.

(16) Value to define upper magnitude cutoff. The value in agreement with the type of magnitude cutoff.

(17) Size of the time interval *s*. The integer multiple of the increment of determinations (e.g. it equals 12, for *s* = 6 years and = 0.5 year).

(18) Size of the time interval *u* (for v type counts only). The integer multiple of the increment of determinations (e.g. it equals 18, for *s* = 9 and = 0.5 years).

(19) Time t_0. The date from which the catalog is reasonably complete for the magnitudes considered in the analysis. For example, the NEIC Global Data Base System has records of events at the beginning of the century and earlier, however, in the M8 algorithm test we set t_0 to be January 1, 1963 since the analysis requires completeness of magnitude 5 events (at least).

(20) Percentages p and p_B. The percentile levels to define what values of a function are abnormally high. By M8 program definition, the highest p (or p_B) percent of values only vote for a TIP.

(21) Interval $_{ex}$. This parameter defines time span for counting votes for a TIP.

(22) Voting thresholds H and G. When the two measures of voting pass these thresholds, i.e. h(t) H and g(t) G, at two successive determinations (t -) and t, the program reports of a TIP starting at t.

(23) Interval . This parameter sets the duration of a TIP.

(24) Choice of printout file. This parameter allows the user to chose between full-size output and short one. In the later, tables of functions' counts are omitted.

(25) Choice to save the "profile". It is convenient to store in a file all the parameters for one run of M8 program. Such "profiles" permit the user to reproduce the results achieved sometimes in the past. On the other hand, they are very helpful when the user makes numerous runs with few changes of parameters. If needed, the program can output all the parameters into a profile of special format, with the name specified by the user.

Because of the limited number of typeface characters used in the M8 program there is a need in the following table which clarifies equivalence of the constants.

Constant	Name in Dialog	Description
M_0	Mo	Magnitude cutoff which defines large events
m	M	Lower magnitude cutoff for the count
M'	MM	Upper magnitude cutoff for the count
M_a	Ma	Magnitude cutoff for the count of aftershocks
t_0	To	The start point of the analysis
T_b	Tb	The beginning of determinations of measures
T_e	Te	The ending of determinations of measures
T_*	T*	A specific time in a given area
dt	dt	The step between determinations of measures
s, *u*, *e*	s, u, e	Intervals of time for determination of measures
τ	Tau	The duration of a TIP
τ_{ex}	Tex	The time span for counting votes
β	beta	The constant for exponential weights in s(t)
γ	d	The power for denominator in s(t)
H, G	H, G	The voting thresholds

6. Running M8 Program

All the parameters of M8 program should be specified by the user either in an interactive dialog or in a "profile" of special format prepared by M8 program or with a help of any DOS text editor. We recommend first to start running M8 program in interactive mode and create some profiles from the program (e.g. with the default values of the parameters). We believe that the program is simple enough and easy to use. We believe also that the user will agree with us running the program. Our experience in distribution of the program at Workshops on earthquake prediction (Lima-Peru, 1986; Trieste, 1988, 1991; Caracas, 1991) shows that it might be very useful to start with an example. The participants of these Workshops performed "postdictions" of the Mexican (1985), Spitak (Armenia, 1988), Loma Prieta (California, 1989), and Limon (Costa Rica, 1991) earthquakes. We suggest the user to begin with one example of application of the M8 algorithm using the available global catalog of mainshocks MS4_NEIC.DAT.

An Example.

Check that C:\M8\M8_EXE directory with M8.EXE is in your PATH and that your working directory has the catalog of mainshocks MS4_NEIC.DAT from the NLDEP Disk # X, then execute **M8**. Opening information will appear on your monitor with the question **Some profile (y-n-name) ? =>** at the bottom.

By convention the program gives in brackets possible answers with a suggestion. If you agree with the suggestion you can answer with **/** , if not you should type in your own answer. Let us start with the default parameters answering **n** to the opening question.

The program will show the default parameters of the M8 algorithm which were used for the prediction of the Loma Prieta 1989 earthquake as a magnitude 7.0+ event in circle centered at 36 N, 120 W, and will ask for **Any changes?(n-y) =>**

In the first run we recommend to go for changes (answer **y**) and correct the file name of the catalog and some other parameters. As an example, let us consider that we want to know whether or not the Great Guam August 8, 1993 magnitude 8.2 earthquake occurred within a TIP diagnosed by the M8 algorithm. After answer **y** the program will ask to specify **Number of block to be corrected?(1-5) =>**

The M8 program parameters are arranged into 5 blocks specifying - (1) catalog of mainshocks and magnitude M_0 that defines earthquakes to be predicted; (2) temporal constants of analysis; (3) areas of investigation; (4) functions; and (5) constants of a TIP diagnostics. In our example we should not change anything but the catalog name, constant M_0, ending of analysis, location and specific time of circle. Thus, we have to make corrections of blocks **1- 3**. Let us start with **1**.

(Note: For a larger set of areas of investigation the list of all parameters may not fit one screen. In such a case the user can go for changes in a block he wants to check.)

The program displays parameters of the first block and asks **Is it correct?(y,n,1-5) =>** No, we want to change the catalog name and set M_0 = 8.0. After **n**, the program will ask for **Name of file with main shocks?(mWestUS.dat) =>** Let us type in **ms4_neic.dat** (we assume that this file is in your working directory). For request **Mo = 7.00 ? =>** type **8.0**. The program will display the first block with your corrections and will ask again **Is it correct?(y,n,1-5) =>** If the corrections are right, type **2** to change T_e.

The program displays parameters of the second block and asks **Is it correct?(y,n,1-5) =>** Here we have to change T_e = 1990/01/01 for 1994/01/01, i.e. the end of the NEIC catalog available. After **n**, the program brings on the screen **(Tb, Te) = (1975, 1, 1, 1990, 1, 1) ? =>** Answer **1975,1,1,1994,1,1**. (It is possible to give shorter answer **,,,1994/** because of convention of numeric input.) Answer to the further requests in this block with **/**'s. After the program displays the second block with your corrections and the message **Is it correct?(y,n,1-5) =>** , check if the corrections are OK, and type **3** to change the settings of areas of investigation.

Now the program displays parameters of the third block and the message **Is it correct?(y,n,1-5) =>** Note that one change in the block was already made when we set M_0 = 8.0. The value of R now is 668 km, but not 281 km as it was for M_0 = 7.0. After **n**, the program brings on the screen **Shape of area?(1 - squares or 2 - circles) : (2) =>** The 2 in brackets indicate that the current choice is "circles". Answer with a **/** or type **2** to accept this shape. For **R = R(Mo) km? (punch 0 for R=R(Mo)) =>** answer with a **/** or type **0** to accept this choice. Next the program displays the area specific info listed in table and asks **Correction, deletion or addition?(c-d-a-n) =>**. Answer **c** for correction and then follow the table below:

Question	Answer
Area No.? => **Latitude?(36.00) =>** **Longitude?(-120.00) =>** **T*: year, month, day?(1989,01,01) =>** **Correction, deletion or addition?(c-d-a-n) =>**	**1** **13** **145** **1993,7,1** **n**

The program displays the second block with your corrections and the message **Is it correct?(y,n,1-5) =>** , check if the corrections correspond to location at 13 N, 145 E in the Mariana Islands and to July 1, 1993, i.e. near the epicenter and about one month before the Guam 1993 earthquake (by convention positive values are given to N and E, and negative - to S and W). Then type **y** to finish changes of the settings.

The program will show the parameters of the M8 algorithm as if we use it for prediction of the Guam 1993 earthquake as a magnitude 8.0+ event in the circle centered at 13 N, 145 E, and will ask for **Any changes?(n-y) =>** Answer **n**.

For **Do you want to print functions?(y-n) =>** , answer **y**. For **Do you want to save a profile?(y-n) =>** , answer **y**. For **Name the profile, please =>** , type some file name, e.g. **guam.rem**. The program starts calculations.

At the end of a run the program reminds that **----- Outputs are in files m8.* -----**. (The contents of these files are described below.) By inspection of the M8.PRI file you can check that the Guam 1993 earthquake did occur in a STIP.

If you do not want to loose results during the next run, rename output files using the MS DOS **ren** command, e.g. execute **ren m8.* guam.*** (we assume that M8.EXE is not in the same working directory).

Changing the algorithm.

The program permits variation of all parameters including the list of functions, so that the user may create his own algorithm which has nothing to do with the M8. In its turn the M8 algorithm is neither optimal nor unique algorithm for intermediate-term prediction of earthquakes. The fact that several large earthquakes were predicted and more than fifty retroactive case-histories of successful predictions are established speaks in its favor. However, after almost ten years of study of premonitory activation we are still in the field of small sample statistics. Thus, the need for additional testing and control experiments in each particular case.

Description of the dialog.

Following is the table of questions of the M8 program dialog and possible answers together with the program responses:

Question	Answer and response of the program
1. Some profile?	y - goes to Q. 2; n - the default is used, goes to Q. 3; the name of profile - goes to Q. 3.
2. Name of profile, please	the name of profile - goes to Q. 3.
3. Any changes?	y - goes to Q. 4; n - goes to Q. 43. Comment: Before this question the table with all parameters considered is displayed.
4. Number of block to be corrected?	1 - goes to Q. 5; 2 - goes to Q. 8; 3 - goes to Q. 12; 4 - goes to Q. 20; 5 - goes to Q. 38.
5. Is it correct?	y - goes to Q. 3; n - goes to Q. 6; an integer from 1 to 5 - see answers to Q. 4. Comment: Before this question block No. 1 concerning the catalog is displayed.
6. Name of file with main shocks?	/ - the file with the displayed name will be used; the name of the file with main shocks which will be used.
7. Mo= *** ?	/ - the displayed value (***) of Mo will be used; the value of Mo which will be used.
8. Is it correct?	y - goes to Q. 3; n - goes to Q. 9; an integer from 1 to 5 - see answers to Q. 4. Comment: Before this question the block No. 2 concerning common time constants is displayed.
9. (Tb,Te)=(***,***)?	/ - the displayed values (***,***) of Tb and Te will be used; the values of Tb and Te which will be used.
10. dt= *** ?	/ - the displayed value (***) of dt will be used; The value of dt which will be used.
11. Time interval for activity estimation?	1 - magnitude thresholds will be defined for time interval (Tb, T*); 2 - magnitude thresholds will be defined for time interval (Tb, Te).
12. Is it correct?	y - goes to Q. 3; n - goes to Q. 13;

	an integer from 1 to 5 - see answers to Q. 4. Comment: Before this question the block No. 3 concerning the space vicinities is displayed.
13. Shape of area?	1 - the areas will be squares; 2 - the areas will be circles.
14. R = *** km?	y - the displayed value (***) of R will be used; / - the displayed value (***) of R will be used. The value of R which will be used. If the answer is 0, the value of R is calculated by formula from comments to the description of the algorithm.
15. Correction, deletion or addition?	c - goes to Q. 16; d - goes to Q. 16; a - goes to Q. 17; n - goes to Q. 12. Comment: Before this question the table of the areas considered is displayed. For each area the coordinates of the center and the date of T* are given.
16. Area No.?	The number of the area to be corrected or deleted (according to the answer in Q. 15).
17. Latitude?	The value of latitude of the center; / - the displayed value will be used.
18. Longitude?	The value of longitude of the center; / - the displayed value will be used.
19. T*: year, month, day?	Values of year, month and day for the date of T* for the area; / - the displayed value of T* will be used.
20. Is it correct?	y - goes to Q. 3; n - goes to Q. 21; An integer from 1 to 5 - see answers to Q. 4. Comment: Before this question the block No. 4 concerning functions of diagnosis is displayed.
21. Correction, deletion or addition?	c - goes to 22; d - goes to 22; a - goes to 23; n - goes to 20. Comment: Before this question the table of functions of diagnosis is displayed.
22. Function No.?	The number of function to be corrected or deleted (according to the answer in Q. 15).
23. Function x?	y - the displayed type (x) of function remains; / - the displayed type (x) of function remains; the type of function to be used. Comment: Before this question the list of general notations of functions which can be used in diagnosis is displayed.
24. Value of ns (s=ns*dt)?	The value of the number (ns) of steps dt in s; / - the displayed value of ns will be used.
25. Value of nu (u=nu*dt)?	The value of the number (nu) of steps dt in u;

	/ - the displayed value of nu will be used.
26. Beginning of the catalog, To = ?	The year to start estimation of long range trend of seismic activity; / - the displayed year will be used.
27. Type of M ?	c - the magnitude threshold will be constant M = a, goes to Q. 28; s - the magnitude threshold will be counted using Mo: M = Mo - a, goes to Q. 29; a - the magnitude threshold will be counted from the activity, goes to Q. 30; y - the displayed type will be used; / - the displayed type will be used.
28. M = a = *** ?	The value of the constant magnitude threshold M = a; / - the displayed value (***) of M will be used.
29. a = Mo - M = ***?	The value of the difference a between Mo and M ; / - the displayed value (***) of a will be used.
30. M = M(a), where a is the average number of shocks per year: a = *** ?	The value of a; / - the displayed value (***) of a will be used.
32. Type of MM?	c - the magnitude threshold will be constant MM = aa, goes to Q. 33; s - the magnitude threshold will be counted from Mo: MM = Mo - aa , goes to Q. 34; a - the magnitude threshold will be counted from the activity, goes to Q. 35; y - the displayed type will be used; / - the displayed type will be used.
33. MM = aa = *** ?	The value of the constant magnitude threshold MM = aa; / - the displayed value (***) of mm will be used.
34. aa = Mo - MM = *** ?	The value of the difference aa between Mo and MM; / - the displayed value (***) of aa will be used.
35. MM = M(aa), where aa is the average number of shocks per year: aa = ***?	The value of aa; / - the displayed value (***) of aa will be used.
36. beta = *** ?	The value of the coefficient for the main shock weights in function s; / - the displayed value (***) of the coefficient will be used.
37. d = *** ?	The value of the power for the number of main shocks summarized in function s; / - the displayed value (***) of the power will be used.
38. Is it correct?	y - goes to Q. 3; n - goes to Q. 39; an integer from 1 to 5 - see answers to Q. 4. Comment: Before this question the block No. 5 concerning the constants for diagnosis of TIP is displayed.
39. Values of percentile p for b (pb) and other	The values of pb and p.

functions(p)?	/ - the displayed values will be used. Comment: pb and p are used in definition of extremely large values of functions.
40. Value of Nex (Tex=Nex*dt)?	The value of the number (Nex) of steps dt in a time window for the definition of "simultaneous" extrema; / - the displayed value of Nex will be used.
41. Values of G and H?	The values of the thresholds for the number of groups of functions with "extremely large" values (G) and the number of such functions (H); / - the displayed values of G and H will be used.
42. Value of Nau (Tau=Nau*dt)?	The value of the number (Nau) of steps dt in the duration of a TIP; / - the displayed value of Nau will be used.
43. Do you want to print functions?	y - the table of values of the functions considered will be written in the file for printing (m8.pri); n - the table will not be written in the file.
44. Do you want to save data in a profile?	y - goes to Q. 45; n - the program starts calculations.
45. Name the profile, please	The name of profile in which the data will be written. The program starts calculations.

Running the batch version of M8

In some cases it might be more convinient not to go through interactive dialog but run M8 from the command line. For this purpose we provide the user with M8_BAT.EXE. To run it, execute **M8_BAT *filename.REM time*** , where ***filename.REM*** is the profile created in a standard of M8 (see Appendix 1) and ***time*** is the file with the date of T_e in free format. This program is used to speed up the update of the M8 algorithm test in Circum Pacific. You can find corresponding batch files RUN_REG.BAT and RUN_TEST.BAT in the M8_TEST subdirectory. To run the January 1, 1994 update in region BM (Bonin-Mariana Trench), go to the M8_TEST subdirectory and execute **RUN_REG BM 940**. To run the July 1, 1993 update in entire Circum Pacific go to the M8_TEST subdirectory and execute **RUN_TEST 935** .

Two auxiliary programs

The user is provided with the two supplementary programs, CAT_M8 and ASC2B20. The first one selects a subcatalog from a catalog in the 20 byte binary format. This program permits the specification of ranges of latitudes and longitudes, i.e. lat_min ≤ latitude ≤ lat_max and lon_min ≤ longitude ≤ lon_max (this area may cross the 180° longitude but its longitudinal size should not exceed 180 degrees). To run CAT_M8 type **CAT_M8 *limits input_catalog output_catalog*** , where ***limits*** is a file with (lat_min, lat_max, lon_min, lon_max) in free format, ***input_catalog*** and ***output_catalog*** are the file names the input catalog and the output subcatalog. The program is useful when the catalog available covers significantly larger territory then an area of investigation, e.g. we use it to speed up execution of updates of the M8 algorithm test in Circum Pacific.

The other program converts an ASCII catalog of mainshocks to the 20 bytes binary format which is used by M8. Each line of an ASCII catalog should contain the following as numbers separated by commas - year (AD), month, day, hour, minute, latitude, longitude (both in degrees), depth (in km), magnitude, number of aftershocks, e.g.: 1993,8,8,8,34,12.96,144.78,60,8.2,75 . By convention positive values of coordinates are °N and °E, and negative - °S and °W. To convert an ASCII catalog named ***ASCII*** to binary catalog named ***BINARY*** execute: **ASC2B20 *ASCII BINARY*** .

7. Output of M8

The M8 program outputs several files: M8.PRI, M8.ERS, M8.TIP, M8.STR, M8.RES (and, optional, profile *.REM). M8.PRI is an easy to read output with the results of the M8 program run. Its heading lists all the values of input parameters. For each area of investigation, i.e. Region, the program reports the annual average rate of all the events from the catalog, including records for the first and the last quakes used in this calculation, and for every function the magnitude range of the count. Next, for each Region, the program compares the annual average rate of all events to the maximal requested rate from the definitions of functions. If the later is greater, the program will give a warning. The program will not perform computations for the region if the rate of activity in it is less than 80% of the requested. If the rate is sufficient for calculations the program reports, if any, the TIP's and "strong quakes", mainshocks with magnitude greater or equal to M_0, in the region. Each TIP is specified by its identification, Region number, coordinates of center and time span.

If requested, these aree followed by the values of counts assembled in a table. The title of the table specifies the Region with its number, T*, and coordinates of the center. Each row lists the voting score g(t):h(t), the maximal magnitude of events observed since the previous determination, the date of determination, and the values of functions (if the function can not be evaluated, the program will mark it with "-"). If the value of a function is "abnormally large" it is accompanied with "*". The voting resulting in a TIP declaration is followed by "***:*" in the next four rows (the program excludes from consideration these four determinations of voting). In addition, each table is preceded by the first record and is followed by the last record of quakes considered for these counts.

The last lines of M8.PRI summarize the number of STIP's, FTIP's, CTIP's and "e.c."'s, and reports statistics of the occurrence of quakes with magnitudes ranging from M_0 - 0.5 to M_0 in the TIP's.

Four supplementary files might be useful for analysis and presentation of the results. M8.ERS contains the coordinates of centers of areas used in the run of M8. M8.STR provides all the "strong quakes" in the catalog during the period of investigation in a special ASCII format (see Appendix 2). M8.TIP lists in a short format all the TIP's determined. Each TIP is specified by its Region number, time span and by the number of "strong quake" in M8.STR that confirmed this alarm (0 for none). M8.RES shows the current state of alarm in all the areas of investigation at T_e (1 for an alarm, 0 for no alarm, -1 for insufficient data).

8. Error Messages and Trouble-Shooting

M8 returns the error messages when it can not find a file of mainshocks or a profile specified by the user. In these cases the program displays input parameters and asks the user to correct them (the batch version of M8 program will terminate the run).

As mentioned above, the program gives warnings when the catalog might be or is insufficient for the analysis.

The author apologizes for not protecting most of the numerical input from mistyping and range inconsistency.

The author strongly recommends the book by R.S. Olson (*11*) for the user who does not want to get into trouble issuing earthquake predictions,.

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Exercises for better understanding the M8 algorithm

Exercise 1:
Seven functions of the M8 algorithm are defined according to the following listing –

No.	Func	Magnitudes M and MM m	mm	a	aa	Intervals s/dt	u/dt	To	beta	d
F1:	n	act		10		12				
F2:	n	act		20		12				
F3:	l	act		10		12		1967		
F4:	l	act		20		12		1967		
F5:	s	act	shf	10	0.50	12			0.46	0.67
F6:	s	act	shf	20	0.50	12			0.46	0.67
F7:	b	shf	shf	2.00	0.20	2				

Form the four groups of functions so that the members of each group differ by a choice of numerical parameters only.

The functions vote for the declaration of a warning or *time of increased probability* (TIP) for an earthquake of magnitude M_0+ in the circle of investigation (CI). Any function cast a vote for a TIP when it is *anomalously large*, i.e., in the top Q% of its empiric range (for `b`, Q% = 25%; for other functions, Q% = 10%).

Exercise 2:
In the two Tables below mark anomalously large values of the M8 functions.

Exercise 3:
In the two Tables below fill the column of votes `g:h` counting the number of groups of the functions, which members voted sometime in the preceding three years (`g`) and the number of functions voted sometime in the preceding three years (`h`).

A time of increased probability is declared for the CI, when `g` equals 4 and `h` is greater than 5 in two successive six-month evaluations. Once a TIP is declared it lasts for five years from the time of declaration.

Exercise 4:
In the two Tables below determine the TIP's, if any.

Tables of the M8 functions in the two CI's

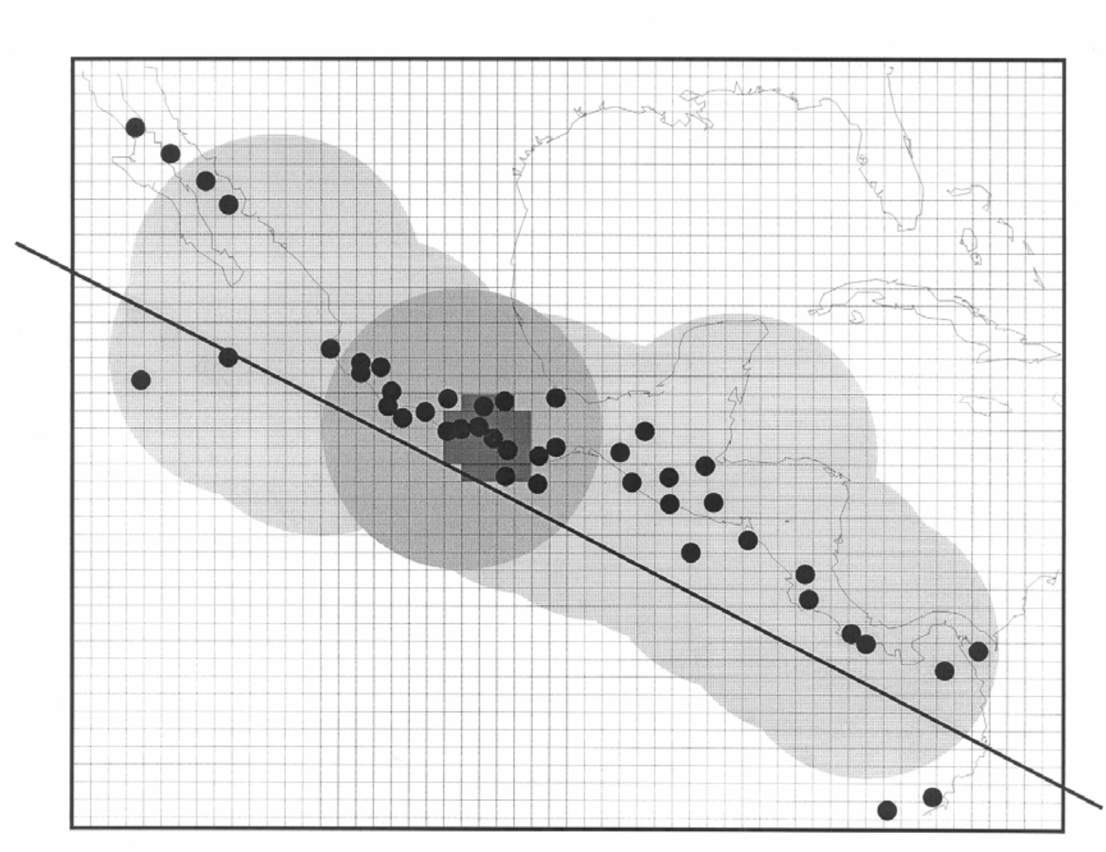
Region No. 7 -1.00 100.00

g:h	Mmax	Date	F1	F2	F3	F4	F5	F6	F7
	6.2	1979/07/03	74	113	0	20	1638	1540	1
	6.6	1980/01/01	75	116	3	24	1726	1602	2
	5.9	1980/07/02	72	113	-2	17	1721	1591	2
	6.3	1981/01/01	71	109	-4	7	1600	1503	2
	5.7	1981/07/02	71	109	-3	7	1583	1488	2
	5.4	1982/01/01	71	112	-2	12	1481	1408	-
	5.9	1982/07/02	76	119	4	19	1419	1368	-
	6.1	1983/01/01	76	121	5	23	1447	1389	1
	5.6	1983/07/03	76	127	5	28	1435	1376	1
	5.6	1984/01/01	77	129	6	30	1421	1366	-
	5.8	1984/07/02	76	130	5	30	1384	1336	-
	7.4	1985/01/01	78	139	8	40	1496	1414	2
	5.4	1985/07/02	70	136	-3	33	1441	1359	2
	5.2	1986/01/01	67	129	-6	26	1333	1283	-
	5.4	1986/07/02	68	129	-5	25	1321	1276	-
	5.4	1987/01/01	68	131	-5	26	1287	1256	-
	6.6	1987/07/03	72	136	0	31	1368	1317	5
	5.2	1988/01/01	69	132	-3	27	1361	1308	5
	5.5	1988/07/02	68	132	-5	24	1336	1291	-
	5.5	1989/01/01	67	136	-5	29	1312	1274	-
	5.8	1989/07/02	64	131	-8	21	1297	1260	-
	5.6	1990/01/01	65	136	-7	26	1304	1270	-
	5.4	1990/07/02	63	134	-9	23	1288	1256	-
	6.8	1991/01/01	69	135	-3	22	1242	1237	6
	6.2	1991/07/03	73	140	0	26	1301	1283	6
	5.8	1992/01/01	78	151	6	39	1336	1314	0
	6.4	1992/07/02	80	158	8	46	1387	1351	3
	5.9	1993/01/01	81	152	9	39	1397	1356	3
	6.2	1993/07/02	76	149	3	35	1356	1319	0
	6.5	1994/01/01	83	155	11	42	1456	1394	1
	7.0	1994/07/02	81	149	9	34	1574	1468	9
	6.2	1995/01/01	91	157	19	42	1626	1524	9
	5.4	1995/07/03	92	155	21	40	1615	1518	0
	7.1	1996/01/01	93	155	22	38	1807	1653	3
	5.5	1996/07/02	90	147	19	30	1812	1656	3
	6.3	1997/01/01	84	139	12	21	1796	1634	0
	5.9	1997/07/02	79	138	6	18	1776	1600	0
	5.9	1998/01/01	80	134	7	13	1786	1618	-
	7.0	1998/07/02	72	121	-1	-1	1828	1633	1
	5.8	1999/01/01	71	124	-2	2	1836	1627	1
	5.4	1999/07/03	73	125	0	3	1788	1602	-
	6.2	2000/01/01	67	123	-7	1	1738	1544	0

Region No. 8 -3.00 101.50

g:h	Mmax	Date	F1	F2	F3	F4	F5	F6	F7
	6.2	1979/07/02	81	136	-1	30	1675	1595	1
	6.6	1980/01/01	81	136	0	29	1754	1649	2
	6.0	1980/07/01	75	131	-7	19	1752	1637	2
	6.3	1980/12/31	72	127	-10	10	1615	1538	2
	5.2	1981/07/02	67	120	-15	2	1589	1510	2
	5.4	1981/12/31	66	122	-15	6	1470	1427	-
	5.9	1982/07/02	67	127	-13	12	1498	1449	-
	6.1	1983/01/01	70	128	-7	14	1523	1471	1
	6.1	1983/07/02	74	140	-3	27	1553	1496	2
	5.6	1984/01/01	74	141	-3	28	1547	1495	2
	6.1	1984/07/01	74	142	-3	27	1519	1475	2
	7.4	1984/12/31	76	149	-1	35	1683	1588	2
	5.7	1985/07/02	73	145	-8	25	1630	1545	2
	6.6	1985/12/31	72	142	-9	22	1580	1513	12
	5.3	1986/07/02	74	138	-5	17	1555	1500	12
	5.4	1987/01/01	77	141	-1	20	1521	1481	-
	6.6	1987/07/02	82	151	5	32	1599	1543	5
	5.4	1988/01/01	82	150	6	31	1599	1542	5
	5.5	1988/07/01	83	153	7	33	1576	1529	-
	5.5	1988/12/31	79	151	4	32	1553	1508	-
	5.8	1989/07/02	73	142	-3	19	1499	1462	-
	5.4	1989/12/31	69	144	-7	21	1479	1441	-
	5.6	1990/07/02	68	140	-8	16	1453	1422	-
	5.7	1991/01/01	67	140	-10	14	1284	1315	-
	6.2	1991/07/02	67	139	-11	10	1319	1333	0
	5.8	1992/01/01	67	143	-11	16	1300	1325	0
	6.4	1992/07/01	73	152	-4	26	1378	1383	3
	5.9	1992/12/31	75	152	-2	25	1406	1407	3
	5.9	1993/07/02	70	145	-7	16	1334	1349	-
	6.5	1993/12/31	73	147	-4	19	1400	1395	0
	7.0	1994/07/02	71	139	-6	10	1523	1467	9
	5.7	1995/01/01	83	154	7	26	1562	1516	9
	5.4	1995/07/02	81	147	5	19	1547	1503	-
	7.1	1996/01/01	81	140	6	11	1669	1587	3
	5.5	1996/07/01	76	132	1	4	1664	1573	3
	5.8	1996/12/31	72	125	-2	-4	1662	1565	-
	6.4	1997/07/02	65	118	-10	-12	1666	1550	2
	5.9	1997/12/31	67	120	-8	-10	1678	1562	2
	7.0	1998/07/02	60	109	-16	-23	1714	1569	1
	5.8	1999/01/01	58	107	-19	-25	1712	1561	1
	5.8	1999/07/02	63	108	-13	-24	1693	1573	-
	6.5	2000/01/01	61	106	-15	-25	1749	1606	1

Exercise 5:
Denote μ-measure of area $A \subseteq C$ being the number, n(A), of epicenters from the sample catalog that fall into A normalized to the total, n(C), of epicenters from the same catalog that fall into the region considered C, i.e., $\mu(A) = n(A)/n(C)$.
Given CI's shaded grey in the Figure below determine the μ-measure of alerted areas of the two approximations (dark circle and darker rectangular zone for the first and the second approximations, correspondingly) using the sample catalog of epicenters (black dots), which do not repeat each other.



Areas of alert in "Central Ambrica" (light grey):
Predictions of the first (dark) and second (darker) approximations and epicenters from the sample catalog (black dots).

Exercise 5*:
Compare the estimates for the same territories in km squared.

Exercise 5:**
Compare the estimates for the projections of the same territories onto the axis of the fault zone (straight line).

Answers:

Exercise 1: `F1 and F2 (n), F3 and F4 (l), F5 and F6 (s), F7 (b)`

Exercise 2 and 3:

```
      STIP  7 ( -1.00: 100.00)*(1996/07/02-2001/07/02)
 Strong quake: 2000/06/04 16:28   -4.72  102.09  33 8.00 in Region No. 7
```

Region No. 7 2001 -1.00 100.00

g:h	Mmax	Date	F1	F2	F3	F4	F5	F6	F7
	6.2	1979/07/03	74	113	0	20	1638	1540	1
	6.6	1980/01/01	75	116	3	24	1726	1602	2
	5.9	1980/07/02	72	113	-2	17	1721	1591	2
	6.3	1981/01/01	71	109	-4	7	1600	1503	2
	5.7	1981/07/02	71	109	-3	7	1583	1488	2
0:0	5.4	1982/01/01	71	112	-2	12	1481	1408	-
0:0	5.9	1982/07/02	76	119	4	19	1419	1368	-
0:0	6.1	1983/01/01	76	121	5	23	1447	1389	1
0:0	5.6	1983/07/03	76	127	5	28	1435	1376	1
0:0	5.6	1984/01/01	77	129	6	30	1421	1366	-
0:0	5.8	1984/07/02	76	130	5	30	1384	1336	-
0:0	7.4	1985/01/01	78	139	8	40	1496	1414	2
0:0	5.4	1985/07/02	70	136	-3	33	1441	1359	2
0:0	5.2	1986/01/01	67	129	-6	26	1333	1283	-
0:0	5.4	1986/07/02	68	129	-5	25	1321	1276	-
0:0	5.4	1987/01/01	68	131	-5	26	1287	1256	-
1:1	6.6	1987/07/03	72	136	0	31	1368	1317	5*
1:1	5.2	1988/01/01	69	132	-3	27	1361	1308	5*
1:1	5.5	1988/07/02	68	132	-5	24	1336	1291	-
1:1	5.5	1989/01/01	67	136	-5	29	1312	1274	-
1:1	5.8	1989/07/02	64	131	-8	21	1297	1260	-
1:1	5.6	1990/01/01	65	136	-7	26	1304	1270	-
1:1	5.4	1990/07/02	63	134	-9	23	1288	1256	-
1:1	6.8	1991/01/01	69	135	-3	22	1242	1237	6*
1:1	6.2	1991/07/03	73	140	0	26	1301	1283	6*
1:1	5.8	1992/01/01	78	151	6	39	1336	1314	0
3:3	6.4	1992/07/02	80	158*	8	46*	1387	1351	3
3:3	5.9	1993/01/01	81	152	9	39	1397	1356	3
3:3	6.2	1993/07/02	76	149	3	35	1356	1319	0
3:3	6.5	1994/01/01	83	155	11	42*	1456	1394	1
3:3	7.0	1994/07/02	81	149	9	34	1574	1468	9*
3:5	6.2	1995/01/01	91*	157*	19*	42*	1626	1524	9*
3:5	5.4	1995/07/03	92*	155	21*	40	1615	1518	0
4:7	7.1	1996/01/01	93*	155	22*	38	1807*	1653*	3
4:7	5.5	1996/07/02	90*	147	19*	30	1812*	1656*	3
***:*	6.3	1997/01/01	84	139	12	21	1796	1634*	0
***:*	5.9	1997/07/02	79	138	6	18	1776	1600	0
***:*	5.9	1998/01/01	80	134	7	13	1786	1618	-
***:*	7.0	1998/07/02	72	121	-1	-1	1828*	1633*	1
3:4	5.8	1999/01/01	71	124	-2	2	1836*	1627	1
1:2	5.4	1999/07/03	73	125	0	3	1788	1602	-
1:2	6.2	2000/01/01	67	123	-7	1	1738	1544	0
1:2	8.0	2000/07/02	64	122	-9	0	1609	1446	0
1:2	6.0	2001/01/01	53	109	-22	-14	1576	1388	0
1:1	5.9	2001/07/02	54	111	-20	-12	1600	1404	0
0:0	5.1	2002/01/01	48	102	-27	-22	1297	1204	-
0:0	5.8	2002/07/02	50	106	-24	-16	1307	1217	-
1:1	7.6	2003/01/01	47	99	-27	-23	1254	1171	21*
1:1	5.7	2003/07/03	45	89	-28	-34	1251	1165	21*

Strong quake: 2000/06/04 16:28 -4.72 102.09 33 8.00 in Region No. 8

Region No. 8 2003 -3.00 101.50

g:h	Mmax	Date	F1	F2	F3	F4	F5	F6	F7
	6.2	1979/07/02	81	136	-1	30	1675	1595*	1
	6.6	1980/01/01	81	136	0	29	1754*	1649*	2
	6.0	1980/07/01	75	131	-7	19	1752*	1637*	2
	6.3	1980/12/31	72	127	-10	10	1615	1538	2
	5.2	1981/07/02	67	120	-15	2	1589	1510	2
1:2	5.4	1981/12/31	66	122	-15	6	1470	1427	-
1:2	5.9	1982/07/02	67	127	-13	12	1498	1449	-
1:2	6.1	1983/01/01	70	128	-7	14	1523	1471	1
0:0	6.1	1983/07/02	74	140	-3	27	1553	1496	2
0:0	5.6	1984/01/01	74	141	-3	28	1547	1495	2
0:0	6.1	1984/07/01	74	142	-3	27	1519	1475	2
1:1	7.4	1984/12/31	76	149	-1	35*	1683	1588	2
1:1	5.7	1985/07/02	73	145	-8	25	1630	1545	2
2:2	6.6	1985/12/31	72	142	-9	22	1580	1513	12*
2:2	5.3	1986/07/02	74	138	-5	17	1555	1500	12*
2:2	5.4	1987/01/01	77	141	-1	20	1521	1481	-
3:3	6.6	1987/07/02	82*	151	5	32*	1599	1543	5*
3:4	5.4	1988/01/01	82*	150	6*	31	1599	1542	5*
3:5	5.5	1988/07/01	83*	153*	7*	33*	1576	1529	-
3:5	5.5	1988/12/31	79	151	4	32*	1553	1508	-
3:5	5.8	1989/07/02	73	142	-3	19	1499	1462	-
3:5	5.4	1989/12/31	69	144	-7	21	1479	1441	-
3:5	5.6	1990/07/02	68	140	-8	16	1453	1422	-
2:4	5.7	1991/01/01	67	140	-10	14	1284	1315	-
1:1	6.2	1991/07/02	67	139	-11	10	1319	1333	0
0:0	5.8	1992/01/01	67	143	-11	16	1300	1325	0
1:1	6.4	1992/07/01	73	152*	-4	26	1378	1383	3
1:1	5.9	1992/12/31	75	152*	-2	25	1406	1407	3
1:1	5.9	1993/07/02	70	145	-7	16	1334	1349	-
1:1	6.5	1993/12/31	73	147	-4	19	1400	1395	0
2:2	7.0	1994/07/02	71	139	-6	10	1523	1467	9*
3:4	5.7	1995/01/01	83*	154*	7*	26	1562	1516	9*
3:4	5.4	1995/07/02	81	147	5	19	1547	1503	-
3:4	7.1	1996/01/01	81	140	6*	11	1669	1587	3
3:4	5.5	1996/07/01	76	132	1	4	1664	1573	3
3:4	5.8	1996/12/31	72	125	-2	-4	1662	1565	-
3:4	6.4	1997/07/02	65	118	-10	-12	1666	1550	2
1:1	5.9	1997/12/31	67	120	-8	-10	1678	1562	2
2:2	7.0	1998/07/02	60	109	-16	-23	1714*	1569	1
1:1	5.8	1999/01/01	58	107	-19	-25	1712	1561	1
1:1	5.8	1999/07/02	63	108	-13	-24	1693	1573	-
1:2	6.5	2000/01/01	61	106	-15	-25	1749*	1606*	1
1:2	8.0	2000/07/01	58	106	-17	-24	1614	1497	1
1:2	6.8	2000/12/31	48	89	-29	-44	1678	1510	2
1:2	5.9	2001/07/02	51	94	-25	-37	1697	1531	2
1:2	5.1	2001/12/31	48	91	-27	-39	1531	1411	-
2:3	6.9	2002/07/02	52	97	-22	-31	1660	1509	21*
1:1	5.8	2003/01/01	52	93	-22	-35	1648	1504	21*
1:1	5.7	2003/07/02	51	88	-22	-40	1612	1483	-

Exercise 4: “Successful” TIP in Region 7 centered at (-1.00; 100.00) from 1996/07/02 to 2001/07/02 and confirmed by the 2000/06/04 strong earthquake of M=8.0 with epicenter coordinated at (-4.72; 102.09).

Exercise 5: $n(C) = 40$, $n(A_1) = 20$ and $n(A_2)=8$ imply $\mu(A_1) = 50\%$ and $\mu(A_2) = 20\%$.

Exercise 5*: $n(C) = 920$ units of area, $n(A_1) = 64\pi$ and $n(A_2) = 22$ imply $\sigma(A_1) = 22\%$ and $\sigma(A_2) = 2.4\%$.

Exercise 5**: $n(C) = 48$ units of length, $n(A_1) = 14$ and $n(A_2)=5$ imply $\lambda(A_1) = 29\%$ and $\lambda(A_2) = 10\%$.