# 8th Workshop on Non-Linear Dynamics and Earthquake Prediction

## 3 - 15 October, 2005

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# Computer Exercises

# User's Guide for Programs EDCAT, CATAL and AFT

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# User's Guide for Programs EDCAT, CATAL, and AFT

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# THE PACKAGE FOR ANALYSIS
# OF EARTHQUAKE CATALOGS

## I. COMMON NOTATIONS

### 1.1 Contents of the package

The package includes the following programs written in Turbo Pascal and C for PC compatible computers:

**EDCAT**
- reorganization of catalogs with different formats into one of the two standard formats (20 or 41 bytes);
- identification of obvious errors and duplicates;
- correction of errors.

**CATAL**
- merging of two catalogs;
- selection of subcatalogs from a given catalog;
- comparison of two catalogs.

**AFT**
- identification of main shocks and aftershocks in a catalog;
- creation of a catalog of main shocks.

Programs **EDCAT, CATAL, AFT** are written by I.M.Primakov and A.A.Soloviev, and incorporate previous versions by I.V.Kuznetzov.

The programming skill is not required from users. Some experience with computers would be helpful.

*To users*.
The programs are modified from time to time according to the experience of its applications.
Any suggestions or information on results obtained will be kindly appreciated. Please send both to Dr.A.A.Soloviev,
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## 1.2 Catalogs

Programs operate on catalogs of earthquakes. Each earthquake in a catalog is described by a vector (*T*, *LA*, *LO*, *DEP*, *mb*, *ms*, *ml*, *mp*) where *T* is the origin time; *LA* and *LO* are latitude and longitude of the epicenter in degrees and decimals (Western longitude and Southern latitude are negative); *DEP* is the focal depth in kilometers; *mb*, *ms*, *ml*, *mp* are four magnitudes (0 usually corresponds to unknown value of magnitude).

In the catalogs of main shocks created by the program **AFT** *mb* is magnitude, *ms* is the number of aftershocks, *ml* = *mp* = 0.

The earthquakes in a catalog should be in ascending order by time.

*Two standards of catalogs*

Program **EDCAT** converts catalogs stored in about 20 formats, which are commonly used in seismological practice, to one of the following two standards:
- 20 bytes binary format;
- 41 bytes ASCII format.

The records are specified in these formats as follows.

*20 bytes binary format*

The first 4 bytes of the first record contain an integer, which is the total number of records in the file (the number of earthquakes plus 1).

For all other records:

| Positions in a record | Contents | Type |
|---|---|---|
| 1-4 | time of the earthquake in minutes A.D. | integer *4 |
| 5-6 | latitude, degrees multiplied by 100 | integer *2 |
| 7-8 | longitude, degrees multiplied by 100 | integer *2 |
| 9-10 | depth, km | integer *2 |
| 11-12 | magnitude *mb* multiplied by 100 | integer *2 |
| 13-14 | magnitude *ms* multiplied by 100 | integer *2 |
| 15-16 | magnitude *ml* multiplied by 100 | integer *2 |
| 17-18 | magnitude *mp* multiplied by 100 | integer *2 |
| 19-20 | macroseismic intensity (not used usually in these programs) | integer *2 |

*41 bytes ASCII format*

For all records:

| Positions in a record | Contents | Format |
| --- | --- | --- |
| 1-4 | year | i4 |
| 5-6 | month | i2 |
| 7-8 | day | i2 |
| 9-10 | hour | i2 |
| 11-12 | minutes | i2 |
| 13-14 | seconds | i2 |
| 15-19 | latitude, degrees multiplied by 100 | i5 |
| 20-25 | longitude, degrees multiplied by 100 | i6 |
| 26-28 | depth, km | i3 |
| 29-31 | magnitude *mb* multiplied by 100 | i3 |
| 32-34 | magnitude *ms* multiplied by 100 | i3 |
| 35-37 | magnitude *ml* multiplied by 100 | i3 |
| 38-40 | magnitude *mp* multiplied by 100 | i3 |
| 41 | macroseismic intensity, 0-9, A, B, C corresponds to I-XII (not used usually in these programs) | a1 |

## 1.3 Menu

All the programs have the same user interface, based on the window menus.

We call a menu a set of windows on a screen. Each window is a box with a header and with one or several values inside. A value may be numerical, logical or text variable. User can move around the menu and select any window he needs. The current window is highlighted. It can be entered to change values. Some windows can be opened to enter the next level menu. The headers of such windows are enclosed in brackets, e.g. **<Magnitude>**.

- To move cursor around the screen or inside the windows, use **arrows, Home, End, PgUp,** and **PgDn** keys.
- To enter current window, press **Enter.**
- To accept value(s) in the window and to leave the window, press **Enter.** If cursor remains in the window it means that selected value is of wrong type or out of range.
- If you do not need some parameter of the string type, replace it by ' ' (i.e. press **SpaceBar** in that window).
- To open the window and to enter the menu of the next level, use function key **F2.** To select files, use **F9.** To abort the program, use **F10.** The keys which can be currently used are shown in the bottom line of the screen.
- To accept all the values in current menu and leave it, returning to the previous level, press **Esc.** When it is possible, the hint **'Esc - Exit'** appears at the bottom of the screen.
- In some windows values can be toggled by pressing **+** or **-**. In this case, **'+/-'** will appear in the bottom line of the screen.

The following windows are common for all programs.

[Control] window.
'???' in this window means some inconsistence in the selected values of the parameters. If there is 'OK' in the window, one may finish parameter selection. Enter the 'Control' window to get explanations in the first case or to start execution in the second.

[Type] window.
In this window one may select, whether full amount of information will be displayed during the program execution [Type-ON], or just the necessary minimum [Type-OFF].

[Print] and [Protocol] windows.
If in the [Print] window you select value ON, then the file for printout will contain complete output. If you select OFF in the [Print] window, then you have an option to create a smaller printout with information about the set of the selected parameters. To do this, choose the value ON in the window [Protocol].

## 1.4 'PROFILE' file

The set of selected values of parameters can be stored in a separate file, called here 'profile'.

The parameters are rather numerous, since the programs are flexible and offer a wide variety of possibilities. At the same time, some computations may differ only in few parameters, while the rest remain the same.

A profile is created in order to avoid the repetition in choosing the values of the parameters.

Default values of parameters will be suggested if you do not use any profile. Several profiles may exist under different names. However, the extension of a profile should be .EDC for EDCAT, .CAT for CATAL, and .AFT for AFT.

## II. PROGRAM EDCAT

Input for the program is a catalog; it has to be stored in one of 21 formats (NEIS, IRIS, ENEL, etc.). Output is a transformed catalog stored in one of the standard formats under the name with extension .DAT. Optional printout file has the name EDC.PRI and contains the input parameters and information about the results. The name of profile for this program should have the extension .EDC.

### 2.1 Modes of operation of the program EDCAT

The following modes are possible:
- **Reorganize** - reorganization of catalog format with verifying some nonsense in the input catalog (incorrect records, time disordering, impossible values of *T*, *LA*, *LO*, *DEP*, *mb*, ... , *mp*) and duplicates. Transformation of magnitudes is also possible.
- **Sort** - Sorting input catalog by time.
- **Edit** - Correction of errors in input catalog with editor options (search, change, delete, insert or add events). In this mode the program operates on 20 bytes format catalogs only.

## 2.2 Mode Reorganize

*Transformation of magnitudes*  [Transform Magnitude - ON]
Catalog may have maximum four different values of magnitudes for each earthquake. Usually they correspond to different magnitude scales and are named *mb, ms, ml, mp* [**Source**] in the input catalog and *MB, MS, ML, MP* [**Target**] in the output catalog.

| EDCAT allows: | [Action] |
|---|---|
| • To swap positions of two magnitudes | [Action - Swapping] |
| • To recalculate any magnitude *m* from input catalog to<br>$M = f(m) = A \cdot m + B$ if *m* is not equal to 0,<br>$M = f(m) = C$ if *m* equal to 0.<br>Coefficients *A*, *B* and *C* have to be entered in the next level menu. Open window **<Source>** to view or change them. | [Action - Recalc]<br><br>[<Source> - *mb, ... , mp*] |
| • To calculate common magnitude *M* in one of the following ways:<br>a) $M = \max\{f(mb), f(ms), f(ml), f(mp)\}$.<br>Values of the coefficients in $f(mb)$, $f(ms)$, $f(ml)$, and $f(mp)$ may be different. They have to be entered in the next level menu.<br>Open window **<Source>** to view and change them.<br>b) $M = \min\{f(mb), f(ms), f(ml), f(mp)\}$<br>Open window **<Source>**<br>c) According to priority in sense of specified preferences. For example, suppose the priority is *mb, mp, ml, ms*. Then $M=MB$ if *MB* is not 0,<br>    $M=MP$ if $MB=0$ and *MP* is not 0,<br>    $M=ML$ if $MB=MP=0$ and *ML* is not 0,<br>    $M=MS$ if $MB=MP=ML=0$ and *MS* is not 0.<br>Another example. If priority *mb, mb, mb, mb* is indicated then the program deals with input magnitude *mb* only.<br><br>In all cases, when $MB=MP=ML=MS=0$, a value named '**blank**' can be assigned to *M*. The priority and blank value have to be entered in the next level menu.<br>Open window **<Source>** to view and change them. | [<Source> - common]<br><br><br><br><br><br>[Select - Max]<br><br>[Select - Min]<br><br>[1 - mb] [2 - mp]<br>[3 - ml] [4 - ms]<br><br><br><br><br>[1 - mb] [2 - mb]<br>[3 - mb] [4 - mb]<br><br>[Blank]<br><br><br>[Select - Priority] |
| • It is possible to replace all values or only zero values in the target position by recalculated value. | [Replace - all values]<br>[Replace - only zeros] |

*Elimination of duplicates*  [Doubles - ON]
**EDCAT** can identify '**Doubles**', i.e. the entries which are very similar, so that they probably correspond to the same earthquake. We assume that two entries, *E1* and *E2*, are duplicates if their corresponding parameters are sufficiently close, i.e.
$$\left| T(E1)-T(E2) \right| \leq dT, \quad \left| LA(E1)-LA(E2) \right| \leq dLA, \ ... \ , \ \left| M(E1)-M(E2) \right| \leq dM.$$
The thresholds *dT, dLA, ... , dM* are entered in the next level
menu.  [<Delta> - Not Standard]

If you prefer not standard values or you want to examine standard values then enter window **<Delta>**, toggle value to **'Not Standard'** and open this window pressing **F2** to change or browse thresholds.

Standard values are:

Del Time = 1 minute
Del Depth = 1 km
Del Latitude = 0.01 degree
Del Longitude = 0.01 degree
Del *Mb* = 0.01
Del *Ms* = 0.01
Del *Ml* = 0.01
Del *Mp* = 0.01

When a double is identified you can :

a) do nothing [Remove - No]
b) always remove the first in the pair [Remove - First]
c) always remove the second in the pair [Remove - Second]
d) choose in dialog the event to be removed [Remove - In Dialog]

***Errors*** [<Range>]

The program can identify events if their parameters are outside some specified range.
If you prefer not standard values [<Range> - Not Standard]
then open window **<Range>** to choose the thresholds.

Standard values are:

$1000 \le$ Year $\le 2001$
$-10 \le$ Depth $\le 999$
$-90 \le$ Latitude $\le 90$
$-180 \le$ Longitude $\le 180$
$0 \le$ Source magnitudes $\le 9$
$0 \le$ Transformed magnitude $\le 9$

The following order of testing is used for each entry:

• Each record is tested, whether its format corresponds to the type of the catalog. If program can not recognize this record, it is displayed. This entry will be skipped in the output.

• Year should be within the given range; month should be within 1-12; day - 1-31; hour - 0-23; minute, second - 0-59; latitude, longitude, depth, source magnitudes and transformed magnitude should be within the given range.

In some catalogs latitude and longitude are given in degrees and minutes, but not in decimals.
Program can check whether [Test minutes - ON]
$0 \le$ Minutes of longitude and latitude $\le 60$

When the first error in input entry is found, the program displays this entry marking its incorrect position. This entry is not tested further.

Events should be in ascending order by time. Program checks it.

The output of **EDCAT** in mode **Reorganize** may be:

catalog in one of the two standard formats [Format - 20, 41]
printout file **EDC.PRI** with a list of errors, duplicates [Print - ON]
and (or) general information about input catalog [Protocol - ON]

## 2.3 Mode Sort

The output catalog ordered by time will be created.
Sorting is applied to entries with sequential numbers
in a specified interval.                                          [Sort from] [Sort to]
File **EDC.PRI** will contain information about input catalog.

## 2.4 Mode Edit (correction of the catalog)

This mode works only with catalog in **20-byte** standard format. Program provides a problem oriented built-in screen editor. To start this editor, move cursor to Control window and press Enter.

Moving in the Editor:
       Search of the record can be made by number                    [Select Line #]
       or by time (Year Month Day Hour Minute)                         [Select Time]
       **Ctrl-PgUp** moves to the beginning of the catalog.
       **Ctrl-PgDn** moves to the end of the catalog.
       **Enter** - to enter and leave working screen.
       **Arrows, Home, End, PgUp, PgDn** - as usual.
       Editing Keys: **Digits** and **BackSpace**
       Insert a line: **F3**
          The inserted line is an exact copy of the next one and is marked on the screen by '**.1**'.
          Certainly you may change it as you wish.
       Delete a line: **F4**
          After deleting a line the numbering does not change.
Save: **F8**
To finish editing and save your work.

*Attention:* Do not exit the Editor pressing **Esc** before saving the results of your edit session.

## III. PROGRAM CATAL

Input is one or two catalogs, which have to be stored in one of the two standard formats (**20** or **41 bytes**). Output is a catalog created by using the input. This catalog may be stored in one of the standard formats, and/or printed, and/or displayed. The names of all catalogs should have the extension **.DAT**. Optional printout file has the name **CAT.PRI**. The name of profile for this program should have the extension **.CAT**.

## 3.1 Modes of operation of the program CATAL

The following modes of operation are possible:
- **Type (t)** — To type/print input catalog starting from some event.
- **Select (s)** — To select a subcatalog from input catalog.
- **Append (p)** — To select a subcatalog from the first catalog and to add this subcatalog at the end or at a specified entry of the second catalog. In the second case, the tail of the second catalog will be overwritten from the number specified in the window **'InsertionIndex'**.

The following modes of operation are used to eliminate '**duplicates**' i.e. different entries, which correspond to the same earthquake (the same definition as for **EDCAT**). For each event from the first catalog the program finds duplicates in the second catalog.

- **Add (a)** — To eliminate these duplicates; then merge the catalogs into a single output catalog (with events ordered in time).
- **Merge (M)** – This mode is the same as **Add** with possibility to take some magnitudes of duplicates from the second catalog.
- **Intersection (i)** – To select all events from the first catalog that have duplicates in the second catalog.
- **Difference (D)** – To select all events from the first catalog that have no duplicates in the second catalog.
- **Equivalence (q)** – To print all duplicates from both input catalogs.
- **Unequiv. (d)** – To print from both input catalogs all events, which have no duplicates.

### *Definition of the input magnitude*                               [<Magnitude>]

In modes **S, p, A, q, D, d, i, M** for selection of events from input catalogs and verification of duplicates, the input magnitude has to be defined. The modes **S** and **p** work with only one input catalog. The window <**Magnitude**> for them is the same as the window <**Source**> in **EDCAT**. The modes **A, q, D, d, i, M** work with two input catalogs. In these modes, options '**common**', '**all**', '**mb**', '**ms**', '**ml**', '**mp**' are possible. If '**common**' is chosen, then all possibilities of recalculation are exactly the same as in the program **EDCAT**. Other options are somewhat different from the program **EDCAT**:

> **all** - no limitations for magnitudes during selection from input catalog. For verification of duplicates thresholds for differences between values of magnitudes have to be specified for each of the four input magnitudes.
>
> **mb** (*ms*, *ml*, *mp*) - the magnitude *mb* (*ms*, *ml*, *mp*) will be chosen only from input catalog without any transformation. Limitation for selection and the threshold for verification of duplicates have to be specified for this magnitude only.

### *Area for selection of earthquakes*                               [<Area>]

The program selects the earthquakes with epicenters from an area specified in geographic coordinates. The boundaries are included. This area can be:

**Rectangle**                                                         [<Area>-Rectangle]
Rectangle is specified by the intervals of latitude and longitude.
It may cross longitude 180°.                                          [<Area>-Polygon Over]

**Polygon**                                                           [<Area>-Polygon]
Polygon is specified by coordinates of its vertices (their total number should not exceed 20) and should not contain a pole.
It may cross longitude 180°.                                          [<Area>-Rectangle Over]

**Set of circles**                                                    [<Area>-Circles]
Circles are available in the mode **Select** only. Circles are specified by its centers and common radius. Total number of circles should not exceed 20. Circles should not cross longitude 180° .

If a rectangle or a polygon crosses longitude 180° then it should not cross longitude 0°. Coordinates of an area have to be entered in the next level menu. Open window <**Area**> to view and change them. In the Polygon option program allows to view it by pressing **F8**.

# IV. PROGRAM AFT

## 4.1 Introductory notes

Input is a catalog of earthquakes in standard **20 bytes** format. Output is a catalog of main shocks. It is stored on a disk in the same format. The common magnitude is in **'mb'** position of the output catalog and the number of aftershocks is in **'ms'** position. The names of the catalogs should have the extension **.DAT**. Optional printout file has the name **AFT.PRI**. The name of profile for this program should have the extension **.AFT**.

The program separates earthquakes into main shocks and aftershocks. Everywhere in these notes $M$ is the magnitude of the main shock. An earthquake is identified as an aftershock of a preceding main shock if the following conditions are satisfied:
- its magnitude does not exceed $M$;
- the distance between their epicenters does not exceed $R(M)$;
- time difference does not exceed $T(M)$;
- modulus of difference in depth does not exceed $H(M)$.

Here $T(M)$, $R(M)$, and $H(M)$ are empirical functions.

If the conditions are satisfied for several preceding main shocks the earthquake is assigned to the latest among the strongest main shocks.

For details of this definition of aftershocks see:
Keilis-Borok,V.I., L.Knopoff, and I.M.Rotwain, Nature, 1980, **283**: 259-263.

For each main shock the following statistics are given in the printout:
- The number of aftershocks $b(e(i))$ during the time interval $e(i)$ after the main shock; here $e(1) < e(2) < ... < e(j) < T(M), j < 5$.
- The weighted sum **Sigma (sg)** counted for these aftershocks.

The value of $b(e(1))$ is recorded as the number of aftershocks in **'mb'** position of the output catalog.

After a strong earthquake (i.e. main shock with $M \geq M_0$) the count of $b(e(i))$ and **sg** is terminated for all preceding main shocks. However, the identification of aftershocks is carried on.

## 4.2 Parameters for definition of aftershocks

Limitations on magnitude of the aftershock $M_a$ may be of the following types:

$\quad$ **Abs** - $Ma1 \leq M_a \leq Ma2$,

$\quad$ **Rel** - $M - dM1 \leq M_a \leq M - dM2$,

$\quad$ **No** - no limitation.

Here $M$ is the magnitude of the main shock, and the constants Ma1, Ma2, dM1, dM2 are specified by a user.

Limitations on depth of the aftershock $H_a$ may be of the same types:
- **Abs** - $Ha1 \leq H_a \leq Ha2$,
- **Rel** - $H - dH1 \leq H_a \leq H - dH2$,
- **No** - no limitation.

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Here $H$ is the depth of the main shock, and the constants Ha1, Ha2, dH1, dH2 are specified by a user.

Limitations on the distance $R_a$ between epicenters may be of the types **Abs** and **No** only:
- **Abs** -   $R_a \le$ Ra1,
- **No** -   no limitation.

Here the constant Ra1 is specified by a user.

Limitations on time $T_a$ between the main shock and its aftershock may be of the type **Abs**:

  **Abs** -   $T_a \le$ Ta1.

Here the constant Ta1 is specified by a user.

## 4.3 Limitations as function of M

We consider main shocks in magnitude range $M_1 \le M \le M_2$. This interval can be subdivided into intervals by k points $c_i$:

$$M_1 < c_1 < ... < c_k < M_2.$$

Limitations of type **Abs** on magnitude, depth, distance, and time, namely Ma1, Ma2, Ha1, Ha2, Ra1, and Ta1, may be common (notation-'**Mono**') for all $M$ or be different (notation '**Poly**') for different intervals.

For example, consider the following limitations on $M_a$:

| | | |
|---|---|---|
| for $M_1 = c_0 \le M < c_1$ | - | Ma1(1) $\le M_a \le$ Ma2(1); |
| for $\quad c_1 \le M < c_2$ | - | Ma1(2) $\le M_a \le$ Ma2(2); |
| ............................................... | | |
| for $\quad c_k \le M < c_{k+1} = M_2$ | - | Ma1(k+1) $\le M_a \le$ Ma2(k+1). |

Here $[c_i, c_{i+1})$ are magnitude intervals with different limitations and Ma1(i), Ma2(i) are corresponding limits. The number $k$ of points of division should be less than 10.

## 4.4 Menu

The program **AFT** selects from the input catalog a subcatalog, for which the separation of earthquakes into main shocks and aftershocks is carried out. This selection is made as in the mode **Select** of the program **CATAL**, however, a set of circles is not accepted.

The value of Sigma for each main shock may be displayed during execution of the program.                                     [Type Sigma-ON]

One may limit the displaying of the main shock to those with the number of aftershocks exceeding some threshold.                                     [Min Number]

To set all the parameters for aftershock selection and identification, described above, move the cursor to the window <**Functions**> and press Enter or **F2**.

| Specified value(s) | Window |
|---|---|
| Number of magnitude intervals, $k + 1$ | [Number of Lines] |
| $M_1, c_1, c_2, \dots , c_k, M_2$ | [Interval] |
| (boundaries of magnitude intervals) | |
| $c$, $d$, and $f$ for calculation of **Sigma** $= \Sigma c10^{dM-f}$ | [c] [d] [f] |
| $M_0$ | [Strong] |
| For each magnitude interval: | |
| Ma1, Ma2, dM1, dM2 | [Magnitude] |
| Ha1, Ha2, dH1, dH2 | [Depth] |
| Ra1 | [Distance] |
| Ta1 | [Time] |
| $e(1), \dots , e(5)$ | [Time1], ... , [Time5] |
| (time interval boundaries) | |