

BOXER User Guide

Version 3.3
(November 2004)

The “Boxer” program was written by Paolo Gasperini in the April of 1999. It is a revised and simplified version of several computer codes which, starting from 1993, have been developed by the author, with the contribution of Filippo Bernardini and Graziano Ferrari, to compute focal parameters of earthquakes from macroseismic data and have also been actually used to compute synthetic earthquake parameters for the *Catalogo dei Forti Terremoti in Italia dal 461 a.C. al 1990* [Boschi et al. 1995, 1997], the *Catalogo Parametrico dei terremoti Italiani (CPTI)* [Gruppo di lavoro CPTI, 1999] and to make the computation of the BSSA paper by Gasperini et al. [1999]. The program also took advantage of important improvements made by Gianfranco Vannucci (particularly regarding the code to generate MapInfo and GMT files) and by Gianluca Valensise (who also suggested the name).

While the macroseismic epicenters, epicentral intensities and azimuths computed by Boxer fully coincide with those published in the above cited papers, the magnitudes may slightly differ (some tenth of magnitude unit at most) due to some differences in the relative weighting of various intensity classes. A description of the procedure to compute the azimuth and to draw the “boxes” representing the seismogenic structures can be found in Gasperini et al. [1999]. More details on the computation of epicenter and magnitude are reported by Gasperini and Ferrari [1995, 1997, 2000].

Changes with respect to previous versions

This last release implements an improved method to compute magnitude using a weighting scheme also including the reliability of empirical regressions for each intensity class (see the description of option card MAGCOEF). As well a procedure to compute the necessary coefficients of magnitude-intensity relations is also provided (see description of option card COMPCOEF). This new method has been actually used for revaluing the magnitudes in the historical seismic catalog [Gruppo di Lavoro CPTI, 2004] in the framework of the recent INGV initiative for the computation of the new seismic hazard map of Italy [Gruppo di Lavoro Mappa di Pericolosità Sismica, 2004]. However, the default magnitude assessment method even for this version remains the same of previous ones. Therefore to use the new method this must be explicitly selected by the MAGCOEF option card. In this manual we also describe the previously undocumented option card MAPINFO directing the program to write import files for the MapInfo Graphic Information System (GIS) and the new GMT option card that activate the writing of input files for plot epicenters and boxes with the General Mapping Tool [Wessel and Smith, 1991]. Other minor changes concerned the formats of input-output files (FORMATI and FORMATE option cards). All significantly modified portion of the text below with respect to previous versions are highlighted with a **yellow shading**.

Input and output

The program reads optional parameters from the file INPPARM.DAT. The earthquake data are read instead from a separate file whose name and format can be specified by the user (see below). Both summary data for each earthquake (date, magnitude etc.) and the list of intensity observations are read from this file. All the files must reside in the same folder with the program executable. The program creates two kind of output: a shorter one on the file OUTSUMMARY.DAT, which contains a record for each earthquake including source parameters, and a longer one on the file

OUTFULL.DAT also including details of computations. The procedure for the estimation of new regression coefficients also creates a file named OUTPARM.DAT which is a copy of file INPPARM.DAT with the new computed coefficients added.

Option cards on file INPPARM.DAT

Each option card includes a “verb” field (from columns 1 to 10) and in most cases even a “parameters” field (from columns 11 to 80). Some option cards are followed by one or more additional data cards with a “parameters” field from columns 1 to 80.

The verb identifies the scope of the card and must be written from column 1 with either upper or lower case characters. A percent character (“%”) in column 1 indicates that the card is a comment and thus the program ignores its content.

An alphabetical list of the available option cards follows:

AZPAR - Assigns parameters of the azimuth computation algorithm

COMPCOEF – Computes new coefficients for Magnitude-Intensity relations

CRAMCOEF – Assigns coefficient of the distance weighting formula in the azimuth algorithm

FILE - Defines the name of the macroseismic input data file

GMT - Directs the program to produce files for GMT.

FORMATE - Specifies the Fortran format of the event summary records of the input data file

FORMATI - Specifies the Fortran format of the intensity observation records of the input data file

LENGCOEF - Assigns coefficients of the fault length formula

MAGCOEF - Assigns coefficients of the magnitude formula using the isoseismal area method

MAPINFO - Directs the program to produce import files for MapInfo.

M-IOCOEF - Assigns coefficients of the magnitude-intensity formula

OUTLOOK - Directs the program to write a fixed format summary file

OUTPUT - Selects the type of output

SELMAG - Defines the minimum magnitude for azimuth computations.

USEMAG - Directs the program to use the magnitude reported on the event summary record

WIDCOEF - Assigns coefficients of the fault width formula

A detailed explanation of the format of each option card is given below:

AZPAR

Assigns the values of the minimum allowed number of data-points and the maximum allowed number of half degree decrements with respect to maximum intensity in the azimuth computation algorithm (see: *Gasperini et al.* [1999]).

Parameter field:

1) Name: *Nmin*

Function: minimum allowed number of data-points

Columns: 11-15

Type: Integer

Default: 3

2) Name: *Ndecr*

Function: maximum allowed number of half degree decrements with respect to maximum intensity

Columns: 16-20

Type: Integer
Default: 4

Additional data cards
None

Example

```
1-----11-----21-----  
AZPAR           6     4
```

COMPCOEF

When this option card is present, it is usually inserted as the first one of the cards deck. It directs the program to run the procedure computing the coefficient of magnitude-intensity regressions on the basis of instrumental magnitudes (taken from the event summary records) associated with macroseismic observations. All option cards (including comments) file located after this card are copied to `OUTPARAM.DAT` file with the exception of `MAGCOEF` and `M-I0COEF`. At the completion of computations new `MAGCOEF` and `M-I0COEF` cards with the computed regression coefficients are added to the end of the deck in `OUTPARAM.DAT`. Thus in order to apply the new parameters to further computations, the file `OUTPARAM.DAT` can be simply renamed as `INPPARAM.DAT`.

Parameter field:

1) Name: *Nmm*

Function: minimum allowed number of intensity observations for each intensity class used for calibrating regressions

Columns: 11-15

Type: Integer

Default: 5

Additional data cards
None

Example

```
1-----11-----21-----  
COMPCOEF           3
```

CRAMCOEF

Assigns the values to the coefficients of the *CRAM* [Berardi et al., 1993] formula to compute the distance weights in the azimuth determination algorithm (see: Gasperini et al. [1999])

$$\Delta I = a + b\sqrt[3]{D}$$

where ΔI is the difference between epicentral and local intensity and D is the epicentral distance. Default values were empirically estimated for Italy by Gasperini et al. [1999].

Parameter field:

1) Name: *Acram*

Function: a coefficient of the *CRAM* equation

Columns: 11-20

Type: Real

Default: -0.46

2) Name: *Bcram*

Function: b coefficient of the *CRAM* equation

Columns: 21-30

Type: Real

Default: 0.93

Additional data cards

None

Example

```
1-----11-----21-----  
CRAMCOEF  -0.3      1.1
```

FILE

Assigns the name of the macroseismic data file containing the event summary records as well as the intensity observation records.

Parameter field:

1) Name: *Filename*

Function: name of the input data file

Columns: 11-80

Type: Alphanumeric

Default: INPUT.DAT

Additional data cards:

none

Example

```
1-----11-----21-----  
FILE      INPUT2.DAT
```

FORMATE

Allows to indicate the Fortran format (embedded in parenthesis) of the event summary records in the input data file. It must contain 9 (or 11) fields in the following order: Year (integer), Month (integer), Day (integer), Hour (integer), Minute (integer), Second (integer), Epicentral Area (alphanumeric), Magnitude (real), Number of intensity points (integer), Standard error of Magnitude (real), Epicentral intensity (real) (the last two fields are only required for the computation of magnitude-intensity coefficients). Tabulation (T fields) can be used to accomplish this order if different.

Parameter field:

none

Additional data cards:

Card 1

1) Name: *Formate*

Function: Fortran format of event summary records

Columns: 1-80

Type: Alphanumeric

Default : (I5 , 5I2 , 15X , A20 , 1X , F5 . 1 , 1X , I5)

Example:

```
1-----11-----21-----31-----41-----
```

FORMATE

```
( 8x , I5 , 5I3 , 1X , A20 , 64x , F3 . 2 , T58 , I4 )
```

FORMATI

Allows to specify the Fortran format (embedded in parenthesis) of the intensity observation records in the input data file. It must contain 4 fields in the following order: Latitude (real), Longitude (real), Intensity (real), Locality name (alphanumeric). Tabulation (T fields) can be used to accomplish this order if different. Latitude and longitude must be given in decimal degrees (not degrees and primes). West longitudes can be specified with a negative sign. Uncertain intensity values (i.e. VII-VIII) may be given as fractional (i.e. 7.5)

Parameter field:

none

Additional data cards:

Card 1

Name: *Formati*

Function: Fortran format of intensity data records

Columns: 1-80

Type: Alphanumeric

Default : (2F7 . 3 , 1X , F4 . 1 , 1X , A20)

Example:

```
1-----11-----21-----31-----41-----
```

FORMATI

```
( 48X , 2F8 . 4 , F6 . 1 , T30 , A20 )
```

GMT

Directs the program to create files for plotting epicenters, boxes etc. with GMT. The 5 binary digits of the unique parameter activate (1) or deactivate (0) the writing of Summary files of epicenters (file names: *epi_input.gmt* and *epi_input.bat*), Summary files of boxes and circles (file names: *box_input.gmt*, *cir_input.gmt* and *box_input.bat*), Single files for epicenters (file names: *ep_year_month_day_area.gmt* and *ep_year_month_day_area.bat*), Single files for boxes or circles (file names: *bx_year_month_day_area.gmt* and *bx_year_month_day_area.bat*), Single files for intensity observation (file names: *qt_year_month_day_area.gmt* and *qt_year_month_day_area.bat*) respectively (*input* is the file name specified in the NAME option card, *year*, *month*, *day* and *area* are the year, month day and epicentral area read from the event summary record for the given earthquake).

Parameter field:

1) Name: *Iexcl*

Function: binary digits activating various GMT files

Columns: 11-15

Type: Integer

Default: 00000

Additional data cards

None

Example

```
1-----11-----21-----  
GMT      11000
```

LENGCOEF

Assigns the values to the coefficients of the formula used to compute fault length from magnitude

$$\text{Log}_{10}(L) = a + bM$$

where M is the magnitude and L is the fault length in kilometers. Default values are empirical estimates for subsurface rupture length of “all types of fault” made by *Wells and Coppersmith* [1993] as a function of moment magnitude.

Parameter field:

1) Name: *Alen*

Function: a coefficient of the fault length formula

Columns: 11-20

Type: Real

Default: -2.44

2) Name: *Blen*

Function: b coefficient of the fault length formula

Columns: 21-30

Type: Real

Default: 0.59

Additional data cards

None

Example

```
1-----11-----21-----  
LENGCOEF -2.11      0.65
```

MAGCOEF

Assigns the values of the coefficients, for different intensity class, of the *Sibol et al* [1987] formula to compute the macroseismic magnitude as a function of the isoseismal area and epicentral intensity

$$M_i = a + b \text{Log}^2(A_i) + cI_0^2$$

where A_i is the isoseismal area for the i -th intensity class, which is computed as

$$A_i = \pi R_i^2$$

where R_i (in Km) is the average epicentral distance of localities belonging to the i -th intensity class. The magnitude of an earthquake is computed as the weighted average of the single estimates made using the intensity classes available for the given earthquake. If the number of intensity classes is 4 or larger the largest and lowest estimates are trimmed off the averaging. Two different methods can be selected to weight the estimates made by different intensity classes. For the older one (the only one available in previous versions of Boxer) the weight is simply assumed inversely proportional to the square of the logarithm of the number of available intensity observations. For the newer one the weight is inversely proportional to the number of intensity observations and to the square of regression standard deviation for the corresponding intensity class (computed during the coefficient computation run activated by COMPCOEF card). For the older method only the values of the 3 coefficients of *Sibol et al.* [1987] formula and the limits of intensity classes need to be reported on data cards described below. For the newer one three additional parameters are needed for each intensity class: the standard deviation of the regression, the weight normalization factor (corresponding to number of intensity observation for a unit weight) and the number of degrees of freedom of the regression (the number of data minus the number of free parameters). If the latter is different from zero for all of intensity classes the newer weighting method is selected. In absence of a MAGCOEF option card or if the third parameter is zero or blank for at least one intensity class, the older weighting method is used. Default values are empirical estimates made for Italy from the data of the *Catalogo dei Forti Terremoti in Italia dal 461 a.C. al 1990* (2) [Boschi et al., 1997] in terms of moment magnitude.

Parameter field:

1) Name: *Ncoef*

Function: number of intensity classes used to compute magnitude

Columns: 11-15

Type: Integer

Default: 10

Additional data cards

Card 1

1) Name: *Aiv(1)*

Function: Lower limit of the intensity class (the higher limit is specified in the next card)

Columns: 1-15

Type: real

Default: see below

2) Name: *Cof(1,1)*

Function: a coefficient of the *Sibol et al* [1987] formula

Type: real

Columns: 16-30

Default: see below

3) Name: *Cof(1,2)*

Function: b coefficient of the *Sibol et al* [1987] formula

Type: real

Columns: 31-45
Default: see below

4) Name: *Coej(1,3)*
Function: *c* coefficient of the *Sibol et al* [1987] formula
Type: real
Columns: 46-60
Default: see below

5) Name: *Std(1)*
Function: standard deviation of the regression (for new weighting method only)
Type: real
Columns: 61-68
Default: see below

6) Name: *Avme(1)*
Function: weight normalization factor (for new weighting method only)
Type: real
Columns: 69-76
Default: see below

7) Name: *Idfe(1)*
Function: degrees of freedom of regression (for new weighting method only)
Type: integer
Columns: 77-80
Default: see below

Cards 2 to *Ncoef*

Same as Card 1 for different intensity classes (with increasing intensity).

Example:

(The example values are the default ones)

1	11	21	31	41	51	61
MAGCOEF	10					
2.	3.554		0.025		0.024	
3.	3.422		0.038		0.023	
4.	3.034		0.074		0.019	
4.5	4.340		0.022		0.015	
5.	3.277		0.103		0.012	
6.	3.829		0.070		0.015	
6.5	4.198		0.094		0.009	
7.	4.394		0.091		0.009	
7.5	5.078		0.110		0.000	
8.	5.348		0.116		0.000	

MAPINFO

Direct the program to produce import files to create tables for MapInfo. The 5 binary digits of the parameter activate (1) or deactivate (0) the writing of import files for MapInfo tables of Summary files of epicenters (file names: *epi_input.mid* and *epi_input.mif*), Summary files of boxes and circles (file names: *box_input.mid*, *box_input.mif*, *cir_input.mid* and *cir_input.mif*), Single files for epicenters (file names: *ep_year_month_day_area.mid* and *ep_year_month_day_area.mif*), Single files for boxes or circles (file names: *bx_year_month_day_area.mid* and *bx_year_month_day_area.mif*), Single files for intensity observation (file names:

qt_year_month_day_area.mid and qt_year_month_day_area.mid) respectively (*input* is the file name specified in NAME option card, *year*, *month*, *day* and *area* are the year, month day and epicentral area read from the event summary record for the given earthquake).

Parameter field:

1) Name: *Iexcl*

Function: binary digits activating various MapInfo import files

Columns: 11-15

Type: Integer

Default: 00000

Additional data cards

None

Example

```
1-----11-----21-----  
MAPINFO 11000
```

M-I0COEF

Assigns the values of the coefficients of the formula to compute macroseismic magnitude from epicentral intensity alone when the data are not sufficient to apply the areal method (see: *Gasperini et al.* [1999])

$$M = a + bI_0$$

where M is the magnitude and I_0 the epicentral intensity.

Default values are calibrated for moment magnitude [*Hanks and Kanamori*, 1979] and have been empirically derived by combining the M_s - I_0 relation estimated by *Rebez and Stucchi* [1999] for the Italian magnitude-intensity database

$$M_s = 0.94(\pm 0.13) + 0.56(\pm 0.017)I_0$$

with the Log M_0 - M_s relation (in dyne cm) estimated for Italy and surrounding areas by *Gasperini and Ferrari* [2000]

$$\text{Log } M_0 = 19.3(\pm 0.3) + 0.96(\pm 0.06)M_s = 20.20 + 0.538I_0$$

and then with the definition of M_w by *Hanks and Kanamori* [1979]

$$M_w = -10.7 + 2/3 \text{Log } M_0 = 2.768 + 0.3584I_0$$

Parameter field:

1) Name: *Aint*

Function: a coefficient of the M-I0 equation

Columns: 11-20

Type: Real

Default: 2.768

2) Name: *Bint*
Function: *b* coefficient of the M-I0 equation
Columns: 21-30
Type: Real
Default: 0.3584

Additional data cards
None

Example
1-----11-----21-----
M-I0COEF 1.5 0.5

OUTLOOK(undocumented)

Direct the program to write a fixed-format summary file

OUTPUT

Select type of output (=1 normal output, >1 long output)

Parameter field:

1) Name: *Iout*
Function: type of output
Columns: 11-15
Type: Integer
Default: 1

Additional data cards
None

Example
1-----11-----21-----
OUTPUT 2

SELMAG

Direct the program to compute the azimuth only for earthquakes with magnitude larger than a given threshold.

Parameter field:

1) Name: *Aminmg*
Function: minimum magnitude threshold above which the azimuth is computed
Columns: 11-15
Type: Real
Default: none (no threshold)

Additional data cards
none

Example

```
1-----11-----  
SELMAG      5.5
```

USEMAG

Direct the program to use the magnitude value specified on the event summary line instead of the computed one.

Parameter field:
none

Additional data cards
none

Example

```
1-----11-----  
USEMAG
```

WIDCOEF

Assigns the values of the coefficients of the formula to compute fault width from magnitude

$$\text{Log}_{10}(W) = a + bM$$

where M is the magnitude and W is the fault length in kilometers. Default values are empirical estimates for subsurface rupture width of “all types of fault” made by *Wells and Coppersmith* [1993] as a function of moment magnitude.

Parameter field:

- 1) Name: *Alen*
Function: a coefficient of the fault width formula
Columns: 11-20
Type: Real
Default: -1.01
- 2) Name: *Blen*
Function: b coefficient of the fault width formula
Columns: 21-30
Type: Real
Default: 0.32

Additional data cards
None

Example

```
1-----11-----21-----  
WIDCOEF    -1.3      0.29
```

References

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