BOXER User Guide

Version 3.1
(January 2001)

The "Boxer" program was written by P. Gasperini in the April 1999. It is a revised and simplified version of several computer codes which, starting from 1993, have been developed by the author, and with the contribution of F. Bernardini and G. Ferrari, to compute focal parameters of earthquakes from macroseismic data and have been actually used to make the computation of the *Catalogo dei Forti Terremoti in Italia dal 461 a.C. al 1990* [*Boschi et al.* 1995, 1997] and of the BSSA paper [*Gasperini et al.,* 1999]. The present version of the program also took advantage of important improvements by G. Vannucci and G. Valensise (who also suggested the name of the program).
While the computed macroseismic epicenter, epicentral intensity and azimuth fully coincide with the published papers, the magnitude may be slightly different (some tenth of magnitude unit at most) due to some differences in the relative weighting of intensity classes. A description of the procedure to determine the azimuth and to draw the "boxes" representing the seismogenic structure can be found in *Gasperini et al.* [1999]. More details on the computation of epicenter and of the magnitude can even be found in *Gasperini and Ferrari* [1995,1997,2000]

Input and output

The program reads optional parameters from the file INPPARM.DAT. The macroseismic 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 points are read from this file. All the files must reside in the same folder with the program executable. The program writes two output files: a short one on the file `OUTSUMMARY.DAT` which contains a record for each earthquake including source parameters, magnitude, azimuth , and a long one on file `OUTFULL.DAT`.See Appendix below for a sample of input and output files.

Option cards on file `INPPARM.DAT`

Each option cards includes a "tag" field (from column 1 to 10) and a "parameters" field from column 11 to 80. Some option card may be followed by one o more additional "data" cards containing a "parameters" field from column 1 to 80.
The tag identifies the purpose of the card and must be written beginning with column 1 with either upper or lower case characters. A percent character ("%") in column 1 indicate comments and make the card content to be ignored by the program.
An alphabetical list of the available option cards tag follows:

AZPAR - Assign parameters of the azimuth computation algorithm
CRAMCOEF – Assigns coefficient of the distance weighting formula in the azimuth algorithm
FILE - Define the name of the macroseismic input data file
FORMATE - Specifies the Fortran format of the event summary records of the input data file
FORMATI - Specifies the Fortran format of the intensity point records of the input data file
LENGCOEF - Assigns coefficients of the fault length formula
MAGCOEF - Assigns coefficients of the magnitude formula using the radius method

MAPINFO - Direct the program to produce graphic input files for MAP-INFO.
M-I0COEF - Assigns coefficients of the magnitude-intensity formula
OUTLOOK - Direct the program to write a fixed format summary file
OUTPUT - Select type of output
SELMAG - Defines the minimum magnitude for azimuth computations.
USEMAG - Direct 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 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
```

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 and the intensity points.

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
FILE        INPUT2.DAT
```

FORMATE

Specifies the Fortran format of the event summary records of the input data file. The format must be embedded in parenthesis. It must contain 9 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). 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
FORMATE
(8x,I5,5I3,1X,A20,64x,F3.2,T58,I4)
```

FORMATI

Specifies the Fortran format of the intensity point records of the input data file. The format must be embedded in parenthesis. 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 degrees with decimals (not primes). West longitude is negative. 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 point records
Columns: 1-80
Type: Alphanumeric
Default : `(2F7.3,1X,F4.1,1X,A20)`

Example:
```
1           11
FORMATI
(48X,2F8.4,F6.1,T30,A20)
```

LENGCOEF

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

$$Log_{10}(L) = a + bM$$

where M is the moment magnitude and L is the fault length in kilometers. Default values are empirical estimates for subsurface rupture length of "all types of fault" according to *Wells and Coppersmith* [1993].

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 of the *Sibol et al* [1987] formula to compute the macroseismic equivalent moment magnitude (*Hanks and Kanamori*, 1979) with the radius method (see *Gasperini et al.* [1999]) for different intensity class. Default values are empirical estimates for Italy from the data of the *Catalogo dei Forti Terremoti in Italia dal 461 a.C. al 1990* [*Boschi et al.*. 1995, 1997].

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: *Coef(1,1)*
   Function: *a* coefficient of the *Sibol et al* [1987] formula
   Type: real
   Columns: 16-30
   Default: see below
3) Name: *Coef(1,2)*
   Function: *b* coefficient of the *Sibol et al* [1987] formula
   Type: real
   Columns: 31-45
   Default: see below
3) Name: *Coef(1,3)*

Function: *c* coefficient of the *Sibol et al* [1987] formula
Type: real
Columns: 46-60
Default: see below

Cards 2 to *Ncoef*
Repeat the above format for different intensity classes (in increasing order of 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 (undocumented)

Direct the program to produce graphic input files for MAP-INFO mapping code.

M-I0COEF

Assigns the values of the coefficients of the formula to compute macroseismic equivalent moment magnitude (*Hanks and Kanamori*, 1979) from epicentral intensity alone when data not enough to apply the radius method (see: *Gasperini et al.* [1999])

$$M = a + bI_0$$

where M is the moment magnitude and I_0 the epicentral intensity. Default values have been empirically estimated on the basis of the italian magnitude-intensity database by *Rebez and Stucchi* [1999]

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, 2-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 moment magnitude

$$Log_{10}(W) = a + bM$$

where M is the moment magnitude and W is the fault length in kilometers. Default values are empirical estimates for subsurface rupture width of "all types of fault" according to *Wells and Coppersmith* [1993].

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

Berardi, R., C. Petrungaro, L. Zonetti, L. Magri and M. Mucciarelli (1993). *Mappe di sismicità per l'area Italiana*, ISMES/ENEL, 51 pp.

Boschi, E., G. Ferrari, P. Gasperini, E. Guidoboni, G. Smriglio and G. Valensise (1995). *Catalogo dei forti terremoti in Italia dal 461 a.C. al 1980*, ING-SGA, Bologna, 973 pp. and a CD-ROM.

Boschi, E., E. Guidoboni, G. Ferrari, G. Valensise and P. Gasperini (1997). *Catalogo dei forti terremoti in Italia dal 461 a.C. al 1990*, ING-SGA, Bologna, 644 pp. and a CD-ROM.

Gasperini, P., and G. Ferrari (1995). Stima dei parametri sintetici, in: E. Boschi et al. (Eds.), *Catalogo dei Forti Terremoti in Italia dal 461 a.C. al 1980,* ING-SGA publ., 96-111.

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Gasperini, P., and G. Ferrari (2000). Deriving numerical estimates from descriptive information:the computation of earthquake parameters. Annali di Geofisica, 43, 729-746.

Gasperini P., Bernardini F., Valensise G. and Boschi E. (1999). Defining Seismogenic Sources from Historical Earthquake Felt Reports, *Bull. Seism. Soc. Am.,* 89, 94-110.

Hanks T. C. e Kanamori H. (1979). A moment magnitude scale. *J. Geophys. Res.*, 84, 2348-2350.

Rebez A. and Stucchi M. (1999). Determinazione dei coefficienti della relazione tabellare Io/Ms, in *Catalogo Parametrico dei Terremoti Italiani,* ING,GNDT,SGA,SSN, 90 pp..

Sibol, M. S., G. A. Bollinger and J. B. Birch (1987). Estimations of magnitudes in central and eastern North America using Intensity and Felt Area, *Bull. Seism. Soc. Am.*, 77, 1635-1654.

Wells, D. L. and K. J. Coppersmith (1994). New empirical relationships among magnitude, rupture length, rupture width, rupture area, and surface displacement, *Bull. Seism. Soc. Am.,* 84, 974-1,002.

Appendix

Sample INPPARM.DAT file:

```
% INPUT TEST FILE
%
% USES CATALOGUE MAGNITUDES
USEMAG
% COMPUTE AZIMUTH ONLY IF M>=5.5
SELMAG    5.5
FILE      TEST
FORMATE   (8x,I5,5I3,1X,A20,64x,F3.2,T58,I4)
FORMATI   (48X,2F8.4,F6.1,T30,A20)
```

Sample of TEST.DAT file

```
   11 DI    79 08 25 07        Area vesuviana        CFTI       6   80   80    40.800 14.380 A 622 38 540 28 M           569 22  48
50043
000018 Miseno                                    40.7861 14.0853   7.5
000015 Napoli                                    40.8554 14.2604   7.5
000019 Nola                                      40.9257 14.5287   8.0
000020 Sorrento                                  40.6243 14.3782   7.0
000017 Nocera Inferiore                          40.7428 14.6418   8.0
000021 Salerno                                   40.6788 14.7654   5.0
 1841 DI 1930 07 23 00 08    Irpinia              CFTI     511 100 100   41.050 15.370 A 678 08 660 30 M 670 05 O 672 04 498 1543
30013
000052 Brescia                                   45.5439 10.2144   4.6
000640 Salˇ                                      45.6057 10.5223   2.5
000100 Vicenza                                   45.5491 11.5492   2.5
000740 Volterra                                  43.4019 10.8590   4.0
008220 Cortona                                   43.2746 11.9864   2.0
012798 Molino                                    43.5659 13.3363   2.0
000611 Ancona                                    43.6031 13.5074   2.5
008255 Filottrano                                43.4344 13.3510   2.0
001765 Sirolo                                    43.5214 13.6201   2.0
005099 Civitanova Marche                         43.3066 13.7296   4.0
001502 Macerata                                  43.2994 13.4524   3.0
001503 Matelica                                  43.2557 13.0094   3.0
001504 Recanati                                  43.4029 13.5499   3.5
001505 Tolentino                                 43.2095 13.2827   3.5
012799 Ussita                                    42.9438 13.1362   3.0
002335 Visso                                     42.9304 13.0878   2.5
```

OUTSUMMARY.DAT file

DATE	TIME	LON	LAT	ME	LOCALITY	NTOT	NAZ	AZIMUTH	RAYLEIGH	KUIPER
08/25/ 79	07:00	40.79	14.39	5.7	Area vesuviana	6	5	087+-053	uniform	uniform
07/23/1930	00:08	41.05	15.36	6.7	Irpinia	511	16	109+-011	<0.01	<0.01
05/07/1984	17:50	41.67	14.06	5.6	Appennino abruzzese	911	3	152+-034	<0.10	uniform

OUTFULL.DAT file

```
Input Cards:

 % INPUT TEST FILE
```

```
%
% USES CATALOGUE MAGNITUDES
USEMAG
% COMPUTE AZIMUTH ONLY IF M>=5.5
SELMAG    5.5
FILE      TEST
FORMATE   (8x,I5,5I3,1X,A20,64x,F3.2,T58,I4)
FORMATI   (48X,2F8.4,F6.1,T30,A20)

Parameters summary

Input file:     TEST.DAT

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

Intensity fmt:  (48X,2F8.4,F6.1,T30,A20)

Magnitude coef:

Intensity       a              b              c

  2.0        3.55400         .02500         .02400
  3.0        3.42200         .03800         .02300
  4.0        3.03400         .07400         .01900
  4.6        4.34000         .02200         .01500
  5.0        3.27700         .10300         .01200
  6.0        3.82900         .07000         .01500
  6.5        4.19800         .09400         .00900
  7.0        4.39400         .09100         .00900
  7.5        5.07800         .11000
  8.0        5.34800         .11600

Cram   coef (a, b):     -.460      .930

M-Io   coef (a, b):      .940      .560

Length coef (a, b):    -2.440      .590

Width  coef (a, b):    -1.010      .320

Use magnitude on event card (if not 0)
```

```
 Compute Boxes only for M .GE.  5.50

*****************************************

 Events summary

*****************************************

 Event                 :   79  8 25  7  0  0  5.7 Area vesuviana
 No. of intensity data :       6

 Computed epicenter    :    40.7948   14.3891
 No. of data used      :       5
 Maximum intensity     :     8.0
 Epicentral intensity  :     8.0

 Moment magnitude      :    6.11
 No. of radii used     :       1

 Used magnitude        :    5.69
 Fault length (Km)     :     8.3
 Fault width (Km)      :     6.5

 Fault azimuth (deg)   :    86.5
 Azimuth std           :    52.7
 No. of data used      :       5
 Rayleigh Test         : uniformity ho hypothesis not rejected
 Kuiper   Test         : uniformity ho hypothesis not rejected

 Box vertices          :    40.8130   14.3385   40.8176   14.4364
                            40.7720   14.3418   40.7765   14.4397


*****************************************

 Event                 : 1930  7 23  0  8  0  6.7 Irpinia
 No. of intensity data :     511

 Computed epicenter    :    41.0536   15.3588
```

```
 No. of data used      :       3
 Maximum intensity     :    10.0
 Epicentral intensity  :    10.0

 Moment magnitude      :    6.69
 Magnitude std         :     .07
 No. of radii used     :       9

 Used magnitude        :    6.72
 Fault length (Km)     :    33.5
 Fault width (Km)      :    13.8

 Fault azimuth (deg)   :   108.9
 Azimuth std           :    10.9
 No. of data used      :      16
 Rayleigh Test         : uniformity ho hypothesis rejected s.l. < 0.01
 Kuiper   Test         : uniformity ho hypothesis rejected s.l. < 0.01

 Box vertices          :    41.1438   15.1887   41.0465   15.5666
                            41.0607   15.1510   40.9633   15.5289


*****************************************

 Event                 : 1984  5  7 17 50  0  5.6 Appennino abruzzese
 No. of intensity data :     911

 Computed epicenter    :    41.6664   14.0571
 No. of data used      :       3
 Maximum intensity     :     8.0
 Epicentral intensity  :     8.0

 Moment magnitude      :    5.82
 Magnitude std         :     .09
 No. of radii used     :       8

 Used magnitude        :    5.64
 Fault length (Km)     :     7.7
 Fault width (Km)      :     6.2

 Fault azimuth (deg)   :   151.6
 Azimuth std           :    33.9
```

```
No. of data used      :       3
Rayleigh Test         : uniformity ho hypothesis tent rej s.l. < 0.10
Kuiper   Test         : uniformity ho hypothesis not rejected

Box vertices          :    41.7064   14.0584   41.6453   14.1026
                           41.6875   14.0117   41.6265   14.0559
```