BOXER User Guide

Version 4.0 (beta)
(June 2010)

Historical background

The original version of the Boxer program was written by Paolo Gasperini, in the month of April 1999, with the contribution of Filippo Bernardini, Gianluca Valensise (who also suggested the name) and Graziano Ferrari. It consisted of a reorganization and standardization of various Fortran codes developed since 1993, which had been used to compute synthetic earthquake parameters of the *Catalogo dei Forti Terremoti in Italia dal 461 a.C. al 1990* (CFTI Versions 1 and 2) [*Boschi et al.* 1995; 1997], the *Catalogo Parametrico dei terremoti Italiani (CPTI)* [*CPTI Working group*, 1999] and to make the computations of *Gasperini et al.* [1999]. The successive public releases of the program up to version 3.3 also took advantage of important improvements made by Gianfranco Vannucci (particularly regarding the production of MapInfo and GMT plotting files). Versions 3.2 and 3.3 of the code have been used to compute the parameters of the *CFTI* versions 3 and 4 [*Boschi et al,* 2000; *Guidoboni et al*., 2007] and of *CPTI* version 04 [*CPTI Working group*, 2004]. The last released version 3.3 also includes a procedure to calibrate magnitude coefficients, based on a set of macroseismic data with known magnitude, which have been employed in a benchmark among different codes, within the ambit of the Neries Network Project of the E.U. Framework Program 6.
A description of the procedure to compute the azimuth and to draw the "boxes" representing the seismogenic sources can be found in *Gasperini et al*. [1999]. More details on the computation of epicenter and magnitude are given by *Gasperini and Ferrari* [1995; 1997; 2000].
Recently, *Gasperini et al*. [2010] have developed new methods to compute the location and the magnitude as well as to estimate parameter uncertainties by the bootstrap approach [*Efron and Tbishirani*, 1986] that are implemented in the present version of the code. *Tripone et al*. [2010] also developed a window-based user-friendly interface to setup the input parameters and to post-process the results that is included in the package.

Changes with respect to previous versions

Some minor changes, mainly concerning the computation of uncertainties, affect the location and magnitude methods used in previous versions (see *Gasperini et al*. [2010]). In particular the uncertainties of epicentral coordinates computed by the barycenter location algorithm and of the fault orientation were corrected so that to represent correctly the variability of averages rather than that of the observations. Furthermore, some computational details of the Rayleigh and Kuiper tests, to assess the uniformity of the azimutal distribution of intensity data used to compute the fault orientation, have been changed according to the recent literature. The latter changes made the Kuiper test more restrictive and might lead to discard orientations that were previously accepted. However, as the Kuiper test does not take into account correctly the weight given to each intensity observation, *Gasperini et al*. [2010] suggested to consider its results only if the Rayleigh test does not reject the uniformity hypothesis. In the practice, this means to discarding the orientation only if both tests do not reject the uniformity hypothesis (*s.l.* > 0.1).
The new location and magnitude methods can be selected by including the ATTLOC and ATTMAG option cards in the input deck. One or more of the 6 the location algorithms described by Gasperini et al. [2010] can be selected, but the old barycentre method is also computed in all cases. The BTSTRP option card activates the computation of bootstrap uncertainties, while the MUSSONDEP card activates the computation of depth according to the method proposed by

Musson [1996] as described in *Gasperini et al.* [2010]. Further option cards INPFOLDER, OUTFOLDER, PATHCD, ELFACT, ATTLCOE, and M-IECATT allow respectively to set the folders containing input and output files (excluding `inpparm.dat`), to change the root device and/or folder of input and output files (excluding `inpparm.dat`), to set the confidence level of uncertainty ellipses or ellipsoids, to set the coefficients of the log-linear attenuation equation [*Pasolini et al.* 2008] used by new location and magnitude methods, and to set the coefficient of the linear relationship between the intensity at the epicenter I_E and moment magnitude M_w. The new output files `outsummary_new.dat` and `outsummary_new.xls` report all the parameters computed for each earthquake and/or location method.
The new code also implements a procedure to recover the results of a program run that have been interrupted for any reason. To recover the job, starting from the earthquake that was being computed at the moment of the interruption, the user must answer 'y' to the program prompt. Any other answer makes the program to restart from the beginning of the input file.

Distribution kit and installation

The software for MS-Windows can be downloaded from the web site http://gaspy.df.unibo.it/paolo/boxer/boxer.htm. The auto-extracting executable file `boxer40kit.exe` includes the following files:

`boxer40.exe` (Boxer program executable)
`inpparm.dat` (Example option card file)
`input.dat` (Example intensity data file)
`outfull.dat` (Example full output file)
`outsummary.dat` (Example summary output file, old format)
`outsummary_new.dat` (Example summary output file, formatted text)
`outsummary_new.xls` (Example summary output file, tab separated text)
`boxer40_package.f` (Fortran source of key routine computing location, magnitude and fault orientation)
`manual40.pdf` (this file)

To install Boxer 4.0 code, copy and run the `boxer40kit.exe` file in a disk folder.
To also install the user-friendly interface, download from the same site the auto-extracting executable file `winboxer10kit.exe` and run it in the same disk folder.

Input and output

The program reads option and parameter cards from the file `inpparm.dat` that must always reside in the same folder of the program executable file. The earthquake intensity data are read instead from another file, which name and format can be specified by the user (see below). For each earthquake, an earthquake identification record (including date, epicentral area, instrumental magnitude, etc.) as well as the intensity observations are read from this file. The subfolder and/or the device where the input and output files reside can be specified by option cards. The program always produces four output files: `outfull.dat`, including all the details of computations in a easily readable format; `outsummary.dat`, kept for compatibility with previous versions, containing a record for each earthquake and only including source parameters computed by the old methods; `outsummary_new.dat` and `outsummary_new.xls`, containing a record for each location method (up to 7 records for each earthquake) and including all of the parameters computed by old and new methods as formatted text and tab-delimited text files respectively (see description of the fields below). The procedure for the estimation of new magnitude coefficients for the old method (COMPCOEF option card) produces the file `outparm.dat` that is a copy of file `inpparm.dat` with the new computed coefficients added at end. Several other files are also generated when the option cards MAPINFO and GMT are present. They are stored within a subfolder tree described below.

Option and parameter cards in file `inpparm.dat`

The order of occurrence of the option cards in the input deck is usually insignificant excepting for the cases of COMPCOEF card (that must be the first one of the deck) and of the multiple appearance of the same option card (the parameters of the last one are retained).
Each option card has a "name" field (from columns 1 to 10) and a "parameter" field (from columns 11 to 200). The MAGCOEFF card is followed by one or more additional parameter cards.
The name of the card must be written starting from column 1, without abbreviations, and using either upper or lower case characters. A percent sign ("%") in column 1 indicates a comment that is skipped by the program (but printed in the `outfull.dat` file).

An alphabetical listing of the available option cards follows:

ATTLCOE – Set values of attenuation function coefficients.
ATTMAG – Compute magnitude by the alternative method using attenuation function.
ATTLOC – Compute location by the new method using attenuation function.
AZPAR - Set parameters of the azimuth algorithm.
BTSTRP – Compute bootstrap uncertainties.
COMPCOEF – Compute new coefficients for magnitude-intensity relations (old method).
CRAMCOEF – Set coefficients of the distance weighting formula of the azimuth algorithm.
ELLIPCL – Set confidence level for uncertainty ellipse and/or ellipsoid.
FILE - Set the name of the macroseismic input data file.
GMT - Produces files for plotting with GMT.
INPFOLDER – Set the name of the subfolder where input files reside.
FORMATE - Set the Fortran format of the event identification records in the input data file.
FORMATI - Set the Fortran format of the intensity observation records in the input data file.
LENGCOEF - Set the coefficients of the formula to compute the fault length from magnitude.
MAGCOEF - Set the coefficients of the formula to compute magnitude from isoseismal areas.
MAPINFO - Produce the import files for MapInfo.
MUSSONDEP – Compute the source depth using *Musson* [1996] method.
M-I0COEF - Set the coefficients of the magnitude-epicentral intensity formula (old method).
M-IECATT - Set the coefficients of the magnitude-intensity at epicenter formula (new method).
OUTFOLDER – Set name of the subfolder where the output files are stored.
OUTLOOK - Create a fixed format summary file for certain applications.
OUTPUT - Set the detail of output in the `outsummary.dat` file.
PATHCD – Set the root path of input and output files.
SELMAG - Set the minimum magnitude for computing fault orientation.
SETGMT – Define the command line to set GMT environment.
USEMAG - Use the magnitude reported in the event identification record.
WIDCOEF - Set the coefficients of the formula to compute the fault width from magnitude.

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

ATTLCOE

This card sets the values of the coefficients and of the reference depth of the log-linear attenuation function (*e.g. Pasolini et al.* [2008]) used by the new location and magnitude methods. A character code (S or E) indicates if a cut of the data at long distances is made (S) or not (E) (see *Gasperini et al.* [2010] for details). If the coefficients and the depth are all zero or blank, they are assumed to be the ones computed by *Pasolini et al.* [2008] or by *Gasperini et al.* [2010] for Italy, depending on the value of the code (S or E respectively). In this case the coefficients of the linear regression between instrumental magnitude and intensity at the epicenter (option card M-IECATT) are also set, basing on the code, to the corresponding values reported by *Gasperini et al.* [2010]. If the option card is missing, no cut is made and the coefficients computed by *Gasperini et al.* [2010] are used.

Parameter field:

1) Name: *Code*
   Function: if S a cut of data at long distances is made, if E no cut is made
   Columns: 11
   Type: Character
   Default: `E`
2) Name: *Aattcoe*
   Function: Coefficient of the linear term
   Columns: 16-25
   Type: Real
   Default: `0.00091`
3) Name: *Battcoe*
   Function: Coefficient of the logarithmic term
   Columns: 26-35
   Type: Real
   Default: `1.17219`
4) Name: *Depref*
   Function: Reference hypocentral depth
   Columns: 36-45
   Type: Real
   Default: `4.487`

Example

```
1---------11---16--------26--------36--------
ATTLCOE   E        0.00091   1.17219     4.487
```

ATTMAG

When this option card is present, the magnitude is computed (also) by the new method, based on a log-linear attenuation equation (see *Gasperini et al.* [2010]).

Parameter field:

1) Name: *Nmmag*
   Function: Minimum number of intensity data needed to compute the magnitude
   Columns: 11-15
   Type: Integer
   Default: `10`

Example

```
1---------11---
ATTMAG       20
```

ATTLOC

When this option card is present, the location is computed (also) by the new method based on a log-linear attenuation equation (see *Gasperini et al*. [2010]). The minimum number of intensity data needed to compute the location, and the method (or methods) to employ can be specified optionally. By default method 4 only is selected.

Parameter field:

1) Name: *Nmloc*
   Function: Minimum number of intensity data needed to compute the location
   Columns: 11-15
   Type: Integer
   Default: `10`
2) Name: *ininc*(1)
   Function: If not 0 or blank, select location method 1
   Columns: 16-20
   Type: Integer
   Default: `0`
3) Name: *ininc*(2)
   Function: If not 0 or blank, select location method 2
   Columns: 21-25
   Type: Integer
   Default: `0`
4) Name: *ininc*(3)
   Function: If not 0 or blank, select location method 3
   Columns: 26-30
   Type: Integer
   Default: `0`
5) Name: *ininc*(4)
   Function: If not 0 or blank, select location method 4
   Columns: 31-35
   Type: Integer
   Default: `1`
6) Name: *ininc*(5)
   Function: If not 0 or blank, select location method 5
   Columns: 36-40
   Type: Integer
   Default: `0`
7) Name: *ininc*(6)
   Function: If not 0 or blank, select location method 6
   Columns: 41-45
   Type: Integer
   Default: `0`

Example

```
1---------11---16---21---26---31---36---41---
ATTLOC       10    0    0    0    1    0    0
```

AZPAR

This card sets the values of the minimum number of data-points needed to compute the orientation, and of the maximum of half degree decrements with respect to maximum intensity to be applied (see: *Gasperini et al*. [1999]).

Parameter field:
1) Name: *Nmin*
   Function: minimum number of data-points needed to compute fault orientation
   Columns: 11-15
   Type: Integer
   Default: 3
2) Name: *Ndecr*
   Function: maximum number of half degree decrements from maximum intensity
   Columns: 16-20
   Type: Integer
   Default: 4

Example
```
1---------11---16---
AZPAR         6    4
```

BTSTRP

If this option card is present, the program computes uncertainties by the bootstrap method. The number of bootstrap replicate sets *Nrepl* is computed as a function of the parameters described below and of the number of intensity data points *Npo* of each earthquake as

$$Nrepl=Nbtstrp+Npo*Fbtstrp$$

Default values for *Nbtstrp* and *Fbtstrp* are assumed only if both of them are zero or blank. If only *Nbtstrp* is zero or blank, the number of replicate sets is simply proportional to the number of intensity data according to the coefficient *Fbtstr*. If only *Fbtstrp* is zero or blank, the number of replicate sets is *Nbtstrp* for all the earthquakes.

Parameter field:
1) Name: *Nminpo*
   Function: Minimum number of intensity data to compute uncertainties by the bootstrap method
   Columns: 11-15
   Type: Integer
   Default: 20
2) Name: *Nbtstrp*
   Function: Minimum number of bootstrap replicate sets
   Columns: 16-20
   Type: Integer
   Default: 20
3) Name: *Fbtstrp*

Function: Factor multiplying the number of data in the formula of the number of boostrap sets
Columns: 21-25
Type: Real
Default: `0.5`

Example
```
1---------11---16---21---
BTSTRP        30  100  0.3
```

COMPCOEF

When this option card is present, it must be inserted at the beginning of the card deck. It indicates that the program must run the procedure to computing the coefficient of magnitude-intensity regressions, on the basis of instrumental magnitudes (taken from the event identification records) associated with macroseismic observations. If the magnitude is absent or zero, the event is not considered for regressions. All option cards (including comments) after this card in the `inpparam.dat` file are copied to the `outparam.dat` file, excepting for MAGCOEF and M-I0COEF. At the end of computations, new MAGCOEF and M-I0COEF cards reporting the computed regression coefficients are added to the end of the deck in `outparam.dat` file. Hence, to use the new parameters in further computations, the file `outparam.dat` can be simply renamed as `inpparam.dat`.

Parameter field:
1) Name: *Nmm*
   Function: minimum number of intensity observations needed for each intensity class used in regressions
   Columns: 11-15
   Type: Integer
   Default: `5`

Example
```
1---------11---
COMPCOEF      3
```

CRAMCOEF

This card sets the values to the coefficients of the *CRAM* [*Berardi et al.,* 1993] formula to compute the distance weights used by the algorithm to determine fault orientation (see: *Gasperini et al.* [1999; 2010])

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

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: Intercept of the *CRAM* equation
   Columns: 11-20

Type: Real
Default: `-0.46`

2) Name: *Bcram*
Function: Coefficient of the *CRAM* equation
Columns: 21-30
Type: Real
Default: `0.93`

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

ELLIPCL

This card sets the confidence level (0 < *c.l.* < 1) at which the semiaxes of uncertainty ellipses and/or ellipsoids are to be computed. If the parameter is ≥1 (and <5) it is assumed as the factor by which the standard (1σ) semiaxes are to be multiplied. In this case the confidence levels are different for ellipses and ellipsoids. For example, if the parameter is 1 the confidence level is *c.l.*=0.3935 for ellipses and *c.l.*=0.1987 for ellipsoids while if the parameter is 2, *c.l.*=0. 0.8647 for ellipses and *c.l.*=0. 738 for ellipsoids.

Parameter field:

1) Name: *Elcl*
Function: Confidence level or multiplying factor for uncertainty ellipses and ellipsoids
Columns: 11-20
Type: Integer
Default: `1.0`

Example
```
1---------11--------
ELLIPCL         0.95
```

FILE

This card sets the name of the intensity data file. The file must reside in the same folder of the program executable or in the folder specified by option cart INPFOLDER. For each earthquake, an identification record must precede the intensity observation records. The Fortran format can be specified by FORMATE and FORMATI option cards.

Parameter field:

1) Name: *Filename*
Function: name of the input data file
Columns: 11-80
Type: Character
Default: `input.dat`

Example
```
1---------11--------21-------- … 71--------
FILE      input2.dat
```

FORMATE

This card sets the Fortran format (embedded in parenthesis) of the event identification records in the input data file. It must contain 9 or 11 fields (depending on the type of computations) with the following ordering: Year (integer), Month (integer), Day (integer), Hour (integer), Minute (integer), Second (integer), Epicentral Area (character), Magnitude (real), Number of intensity points (integer), Standard error of Magnitude (real), Epicentral intensity (real). The last two fields are required only for the computation of magnitude-intensity coefficients (see COMPCOEF card). Tabulation (T fields) can be used if the ordering of fields in the user record is different.

Parameter Field:
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------- … 71-------
FORMATE   (8x,I5,5I3,1X,A20,64x,F3.2,T58,I4)
```

FORMATI

This card sets 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 if the ordering of fields in the user records is different. Latitude and longitude must be given in decimal degrees (not primes). Westward longitudes and southward latitudes can be specified with a negative sign. Uncertain intensity values (i.e. VII-VIII) may be given as semi integer values (i.e. 7.5). Other non standard intensity values (*e.g.* 9.1, 3.9, 4.6) are accepted but but their specific treatment is at user risk.

Parameter Field:
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------- … 71-------
FORMATI   (48X,2F8.4,F6.1,T30,A20)
```

GMT

When this option card is present, the program provides the files for plotting epicenters, boxes etc. using GMT [*Wessel and Smith*, 1991; 1998]. The first 2 binary digits of the parameter activate (1) or deactivate (0) the production of summary files with epicenters (epi_m*method_input*.gmt and .bat) as well as summary files with boxes (box_m*method_input*.gmt and .bat), if the orientation is computed or circles (cir_m*method_input*.gmt and .bat) if not. They are stored in the subfolder GMT\SUMMARY of the output folder. The last 3 digits activate the production of individual files for each earthquake with epicenters (ep_m*method_year_month_day_area*.gmt and .bat), boxes or circles (bx_m*method_year_month_day_area*.gmt and .bat or ci_m*method_year_month_day_area*.gmt and .bat) or intensity observations (qt_m*method*_year*_month_day_area*.gmt and .bat) that are stored in subfolders GMT\INDIVIDUAL*year_month_day_area* subfolders of the output folder. In file or folder names, *method* is the location method number (0-6), *input* is the file name specified in the FILE option card, *year*, *month*, *day* and *area* are the year, month, day and epicentral area respectively reported in the event identification record for the given earthquake.

Parameter field:
1) Name: *Iexcl*
   Function: binary digits activating various GMT files
   Columns: 11-15
   Type: Integer
   Default: `00000`

Example
```
1---------11---
GMT       11000
```

INPFOLDER

This option card sets the name of the subfolder where input files must reside. The name must be a valid folder name for the operating system used and must not include blank characters. If the option card is absent, the input file is assumed to reside in the same folder containing the program executable file.

Parameter field:
1) Name: *Foldername*
   Function: Name of the subfolder containing the input data file
   Columns: 11-80
   Type: Character
   Default: `FILEINPUT`

Example
```
1---------11--------21-------- … 71--------
FILE      input_data_folder
```

LENGCOEF

This card sets the values of the coefficients of the formula used to compute fault length L (in km) from moment magnitude M_w

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

Default values are the empirical coefficients of the subsurface rupture length (RLD) for "all types of faults" computed by *Wells and Coppersmith* [1993].

Parameter field:
1) Name: *Alen*
   Function: Intercept of the fault length formula
   Columns: 11-20
   Type: Real
   Default: `-2.44`
2) Name: *Blen*
   Function: Coefficient of the fault length formula
   Columns: 21-30
   Type: Real
   Default: `0.59`

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

MAGCOEF

This card sets 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 isosesismal areas and of epicentral intensity

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

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 oldest versions of Boxer) the weight is simply assumed as inversely proportional to the square of the logarithm of the number of available intensity observations. For the newer method 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 selected 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 are need on data cards described below. For the newest 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). In absence of a MAGCOEF option card or if the third parameter is zero or blank for at least an 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: *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
4) Name: *Coef(1,3)*
   Function: *c* coefficient of the *Sibol et al* [1987] formula
   Type: real
   Columns: 46-60
   Default: see below
5) Name: *Stdr(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--------
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

When this option card is present, the program produces the import files for displaying epicenters, boxes etc., using MapInfo. The first 2 binary digits of the parameter activate (1) or deactivate (0) the production of summary files with epicenters (epi_m*method_input*.mif and .mid) as well as summary files with boxes (box_m*method_input*.mif and .mid) if the orientation is computed, or circles (cir_m*method_input*.mif and .mid) if not They are stored in subfolder MAPINFO\SUMMARY of the output folder. The last 3 digits activate the production of individual files for each earthquake with epicenters (ep_m*method_year_month_day_area*.mif and .mid), boxes or circles (bx_m*method_year_month_day_area*.mif and .mid or ci_m*method_year_month_day_area*.mif and .mid) or intensity observations (qt_m*method*_year_*month_day_area*.mif and .mid) that are stored in subfolders MAPINFO\INDIVIDUAL*year_month_day_area* subfolders of the output folder. In file or folder names, *method* is the location method number (0-6), *input* is the file name specified in the FILE option card, *year*, *month*, *day* and *area* are the year, month, day and epicentral area respectively reported in the event identification 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

Example
```
1---------11---
MAPINFO   11000
```

MUSSONDEP

If this option card is present, the program computes the depth by the *Musson* [1996] method using the parameters indicated in the parameter field or using default values, if zero or blank.

Parameter field:
1) Name: *Alpha*
   Function: Attenuation constant

Columns: 11-20
Type: Real
Default: `0.0061`

1) Name: *Gamma*
Function: Coefficient relating intensity to physical ground motion
Columns: 21-30
Type: Real
Default: `3.2761`

Example

```
1---------11--------21--------
MUSSONDEP      0.003       3.0
```

M-I0COEF

This card sets the values of the coefficients of the formula to compute macroseismic magnitude M from epicentral intensity I_0.

$$M = a + bI_0$$

When the data are insufficient to apply the isoseismal areas method (see: *Gasperini et al*. [1999]) this value is reported in the `outsummary.dat` file. Default values are calibrated for moment magnitude [*Hanks and Kanamori*, 1979] and have been empirically derived by combining the Ms-I_0 relation estimated by *Rebez and Stucchi* [1999] for the Italian magnitude-intensity database

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

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

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

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

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

Parameter field:

1) Name: *Aint*
Function: intercept of the M-I0 equation
Columns: 11-20
Type: Real
Default: `2.768`

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

Example

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

M-IECATT

This card sets the values of the coefficients of the formula to compute macroseismic magnitude M from intensity at the epicenter I_E by the alternative method proposed by *Gasperini et al.* [2010]

$$M = a + bI_E$$

They are also set by the option card ATTLCOE, according to the value of *Code* (S or E), when the coefficients of attenuation equation are set to default values for Italy.

Parameter field:

1) Name: *Amg*
   Function: intercept of the M-IE equation
   Columns: 11-20
   Type: Real
   Default: `5.368/2.3638`
2) Name: *Bmg*
   Function: coefficient of the M-Ie equation
   Columns: 21-30
   Type: Real
   Default: `1./2.3638`

Example
```
1---------11--------21--------
M-IECATT        2.267     0.423
```

OUTFOLDER

This option card sets the name of the subfolder where output files are to be stored. The name must be a valid folder name for the operating system used and must not include blank characters. If the option card is absent, the output files are stored in the same folder containing the program executable file.

Parameter field:

1) Name: *Foldername*
   Function: Name of the subfolder containing the input data file
   Columns: 11-80
   Type: Character
   Default: `OUTPUT`

Example
```
1---------11--------21-------- … 71--------
FILE      output_data_folder
```

OUTLOOK(undocumented)

When this option card is present, the program produces a fixed-format summary file used by some applications.

OUTPUT

This card set the detail of output (=1 normal output, >1 long output) in the `outfull.dat` file.

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

Example
```
1---------11---
OUTPUT        2
```

PATHCD

This option card sets the root device or folder containing input and output files (or subfolders).

Parameter field:
1) Name: *Foldername*
   Function: Name of the device or subfolder
   Columns: 11-80
   Type: Character
   Default: `None` (current folder)

Example
```
1---------11--------21-------- … 71--------
PATHCD    D:\boxerfolder
```

SELMAG

When this option card is present, the program computes the azimuth only for earthquakes with magnitude not lower than the 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)

Example

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

SETGMT

This option card defines the shell command to set the environment variables for GMT (complete path to the gmtenv file). This line is reported at the beginning of each .sh or .bat file produced by the program to plotting results by GMT (see option card GMT).

Parameter field:

2) Name: *phgm*
   Function: shell command line
   Columns: 11-80
   Type: Character
   Default: `gmtenv.bat`

Example

```
1---------11--------21--------31-------- … 71--------
SETGMT    C:\gmt\src\gmtenv.bat
```

USEMAG

When this option card is present, the program uses the instrumental magnitude reported in the event identification record to compute the length and the width of the fault, in place of the computed value.

Parameter field:
none

Example

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

WIDCOEF

This card sets the values of the coefficients of the formula to compute fault width W from magnitude M

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

Default values are the empirical coefficients of the downdip rupture width (RW) for "all types of faults" computed by *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
```

Format of `outsummary_new.dat` and `outsummary_new.xls` files

Such files report the 85 fields listed below as formatted text and tab-delimited text files respectively. The first record contains a header with the synthetic names of the fields. A value of 999 indicates that the parameter is unknown. "Columns" indicates the first and last columns of the field in the `outsummary_new.dat`.

Name	Type	Columns	Description
ID	Integer	1-6	Earthquake identification number
MT	Integer	9	Location method (0-6)
RLAW	Character	11	Long distance cut code (S or E)
YEAR	Integer	13-16	Year
MONTH	Integer	18-19	Month
DAY	Integer	21-22	Day
HOUR	Integer	25-26	Hour
MINUTE	Integer	28-29	Minute
ES			Unused
LAT	Real	35-42	Epicentral latitude (in decimal degrees)
LAT_ERH	Real	44-51	Latitude formal uncertainty (in km)
LAT_BST	Real	53-60	Latitude bootstrap uncertainty (in km)
LON	Real	62-69	Epicentral longitude (in decimal degrees)
LON_ERH	Real	71-78	Longitude formal uncertainty (in km)
LON_BST	Real	80-87	Longitude bootstrap uncertainty (in km)
DEPTH	Real	89-96	Hypocentral depth (in km)[1]
DEP_ERH	Real	98-105	Depth formal uncertainty (in km)
DEP_BST	Real	107-114	Depth bootstrap uncertainty (in km)
TL			Unused
ME	Real	117-122	Preferred magnitude (among old, alternative and I0 methods)[2]
ME_ERH	Real	124-129	Preferred magnitude formal uncertainty
ME_BST	Real	131-136	Preferred magnitude bootstrap uncertainty
TM	Character	138	Preferred magnitude type (n, o, a, i)[3]
LOCALITY	Character	140-179	Epicentral area geographic indication
NTOT	Integer	181-185	Number of intensity data
NAZ	Integer	187-191	Number of intensity data used to compute fault orientation
NBSTR	Integer	193-198	Number of bootstrap replicate sets
AZIM	Real	201-206	Fault orientation (in degrees)
A_ERR	Real	208-212	Fault orientation formal uncertainty (in degrees)
A_BST	Real	214-286	Fault orientation bootstrap uncertainty (in degrees)
RAYLEIGH	Real	220-227	Rayleigh test significance level
KUIPER	Real	229-236	Kuyper test significance level
I0	Real	238-242	Epicentral intensity I0 (method 0) or intensity at epicenter IE (methods >0)
I_ERH	Real	244-248	Formal uncertainty of I0 or IE
I_BST	Real	250-254	Bootstrap uncertainty of I0 or IE
IM	Real	256-260	Maximum intensity
LENGTH	Real	262-269	Fault length
LEN_BST	Real	271-278	Fault length bootstrap std
WIDTH	Real	280-287	Fault width

WID_BST	Real	289-296	Fault width bootstrap std
CONF_LEVEL	Real	298-307	Confidence level or factor[4] of uncertainty ellipses or ellipsoids
EL_AXMX	Real	309-316	Semi-major-axis of formal uncertainty ellipsoid (in km)
EL_AZMX	Real	318-325	Azimuth of major-axis of formal uncertainty ellipsoid (in degrees)
EL_PLMX	Real	327-334	Plunge of major-axis of formal uncertainty ellipsoid (in degrees)
EL_AXMD	Real	336-343	Semi-medium-axis of formal uncertainty ellipsoid (in km)
EL_AZMD	Real	345-352	Azimuth of medium-axis of formal uncertainty ellipsoid (in degrees)
EL_PLMD	Real	354-361	Plunge of medium-axis of formal uncertainty ellipsoid (in degrees)
EL_AXMI	Real	363-370	Semi-minor-axis of formal uncertainty ellipsoid (in km)
EL_AZMI	Real	372-379	Azimuth of minor-axis of formal uncertainty ellipsoid (in degrees)
EL_PLMI	Real	381-388	Plunge of minor-axis of formal uncertainty ellipsoid (in degrees)
EL_BAXMX	Real	390-397	Semi-major-axis of bootstrap uncertainty ellipsoid (in km)
EL_BAZMX	Real	399-406	Azimuth of major-axis of bootstrap uncertainty ellipsoid (in degrees)
EL_BPLMX	Real	408-415	Plunge of major-axis of bootstrap uncertainty ellipsoid (in degrees)
EL_BAXMD	Real	417-424	Semi-medium-axis of bootstrap uncertainty ellipsoid (in km)
EL_BAZMD	Real	426-433	Azimuth of medium-axis of bootstrap uncertainty ellipsoid (in degrees)
EL_BPLMD	Real	435-442	Plunge of medium-axis of bootstrap uncertainty ellipsoid (in degrees)
EL_BAXMI	Real	444-451	Semi-minor-axis of bootstrap uncertainty ellipsoid (in km)
EL_BAZMI	Real	453-460	Azimuth of minor-axis of bootstrap uncertainty ellipsoid (in degrees)
EL_BPLMI	Real	462-469	Plunge of minor-axis of bootstrap uncertainty ellipsoid (in degrees)
E2_AXMX	Real	471-478	Semi-major-axis of formal uncertainty ellipse (in km)
E2_AZMX	Real	480-487	Azimuth of major-axis of formal uncertainty ellipse (in degrees)
E2_AXMI	Real	489-496	Semi-minor-axis of formal uncertainty ellipse (in km)
E2_AZMI	Real	498-505	Azimuth of minor-axis of formal uncertainty ellipse (in degrees)
E2_ECC	Real	507-514	Eccentricity of formal uncertainty ellipse
E2_BAXMX	Real	516-523	Semi-major-axis of bootstrap uncertainty ellipse (in km)
E2_BAZMX	Real	525-532	Azimuth of major-axis of bootstrap uncertainty ellipse (in degrees)
E2_BAXMI	Real	534-541	Semi-minor-axis of bootstrap uncertainty ellipse (in km)
E2_BAZMI	Real	543-550	Azimuth of minor-axis of bootstrap uncertainty ellipse

			(in degrees)
E2_BECC	Real	552-559	Eccentricity of bootstrap uncertainty ellipse
AATT	Real	561-570	Linear term coefficient of attenuation equation[1]
AATT_ERH	Real	572-581	Formal uncertainty of linear term coefficient
BATT	Real	583-592	Logarithmic term coefficient of attenuation equation[1]
BATT_ERH	Real	594-603	Formal uncertainty of logarithmic term coefficient
MM	Real	605-610	Macroseismic magnitude (old method)
MM_ERHM1	Real	612-617	Old magnitude type i formal uncertainty
MM_ERHM2	Real	619-624	Old magnitude type ii formal uncertainty
MM_BSTM	Real	626-631	Old magnitude bootstrap uncertainty
MT	Real	633-638	Macroseismic magnitude from I0
MT_ERHM	Real	640-645	I0 magnitude formal uncertainty
MT_BSTM	Real	647-652	I0 magnitude bootstrap uncertainty
MM2	Real	654-659	Macroseismic magnitude (alternative method)
M2_ERHM	Real	661-666	Alternative magnitude formal uncertainty
M2_BSTM	Real	668-673	Alternative magnitude bootstrap uncertainty
MS	Real	675-680	Instrumental magnitude
MS_ERHM	Real	682-687	Instrumental magnitude uncertainty

Notes:

[1]Reported depth and attenuation coefficients reflect the assumed default values for location method that do not compute them.

[2]Preferred magnitude is chosen depending on the availability of the estimates made by various methods, using the following order of priority: i) old method by modified *Sibol et al.* [1987] formula, ii) alternative method using the attenuation equation, iii) empirical regression with epicentral intensity.

[3]*n* stands for the old method with new weighting scheme, *o* for the old method with old weighting scheme, *a* for the alternative method, and *i* for the regression with epicentral intensity.

[4]If the reported value is lower than 1.0, it indicates the confidence level at which uncertainty ellipses and ellipsoids are computed. If instead the reported value is larger or equal 1.0 it indicates the factor by which standard (1σ) ellipse and ellipsoid semiaxes are multiplied.

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