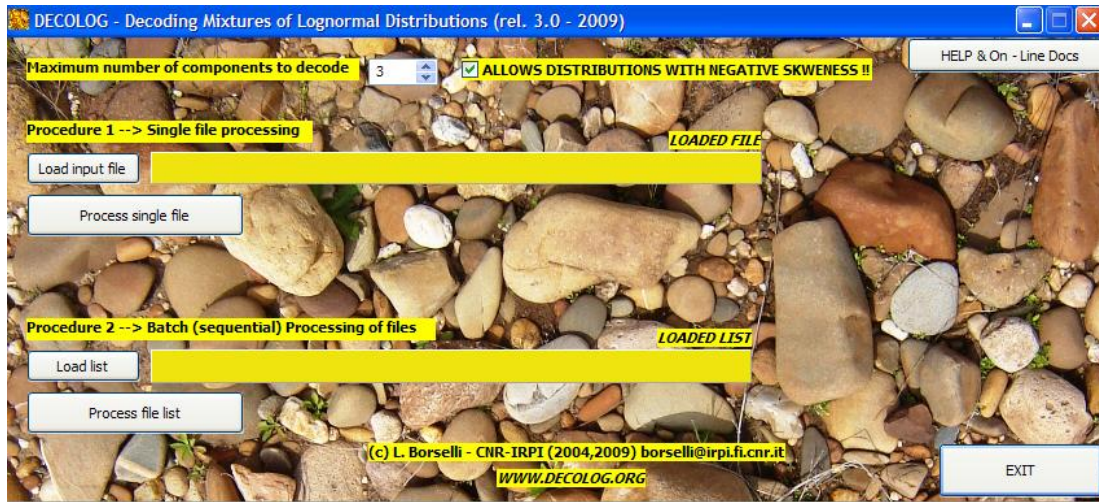
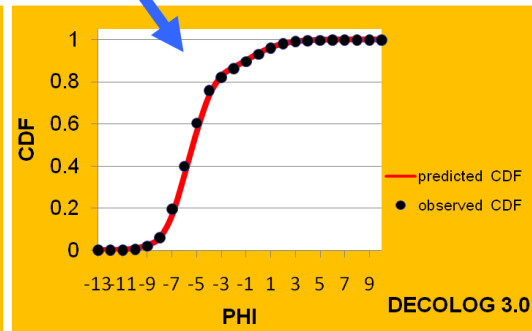
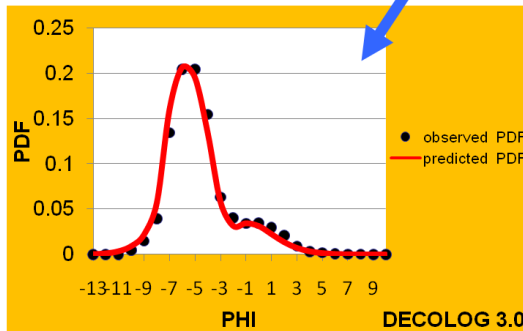
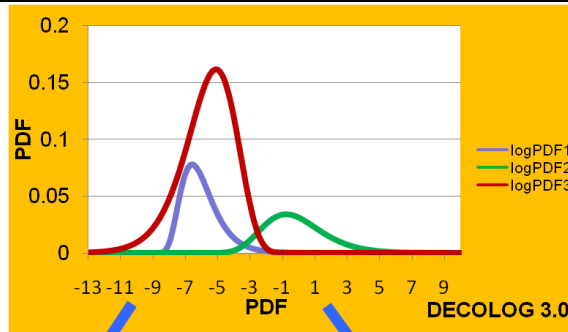


# DECONVOLUTION OF MIXTURES OF LOGNORMAL COMPONENTS INSIDE PARTICLE SIZE DISTRIBUTIONS

DECOLOG 3.0  
By  
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(2004-2009)



**DECOLOG**  
(rel 3.0 - 2004-2009) :  
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## 1-Aims of DECOLOG software

Experimentally derived particle size distribution often shown multimodal shape and this characteristic is usually interpreted as a mixture of two or more populations. The origin of these mixture has been commonly interpreted as due to the complex processes linked to the origin of the sediment and clasts, to the transport and final deposition, or in other terms, the geological cycle of sediment transport and evolution, the weathering and pedogenetic process may affect the final distribution of particles present in the sampled deposit.

The basic idea that all the processes responsible of the deposit leave some trace of them in the special characteristics of the mixture and their population. We assume that the mixture maintain encoded in its global distribution

Aim of DECOLOG software is develop a solution to decode the information present in the natural mixture of particles/sediments using, as paradigm, the log-normal distribution and particularly a defined mixture of these distributions.

DECOLOG performs this operation using innovative techniques of optimization and in automatic way without needs of special efforts from user as the initial guessing of Peaks of the observed distribution ... the easiness of use is one of the most innovative and appreciated characteristics of current version of DECOLOG

This software is released as FREEWARE for the scientific community. This imply that is released and downloadable for free, but without warranties .

The authors of this software want acknowledge the people that with their testing activities and suggestions help us to improve the performance of DECOLOG. Suggestions from the future users are welcomed and greatly appreciated.

## 2-The new release 3.0 of DECOLOG

**The release 3.0 of DECOLOG contains some improvements and mainly an important upgrade.**

**The main upgrade is the new optimization engine that allows to consider components (lognormal distributions) with negative skewness (so left tailed). To do that we use a generalized four parameters lognormal distribution.**

**The internal optimization engine of DECOLOG has been greatly improved using last findings in Multiobjective optimization algorithms based on Differential evolution (DE) and trigonometric differential evolution(TDE). That's improving the speed of convergence and reliability and reproducibility of final results. The new optimization engine has been also implemented in old version of the software. So a new updated version DECOLOG 2.2 is provided with the new one DECOLOG 3.0**

## 3-The log<sub>2</sub> grain size scale in sedimentology.

The grains size distribution, according to sedimentological standard, is expressed in PHI scale (Wentworth scale):

$$\phi = -\log_2 X \quad [1]$$

And the alternative is the PSI scale:

$$\psi = \log_2 X \quad [2]$$

where

$X$  is the grains size diameter (mm).

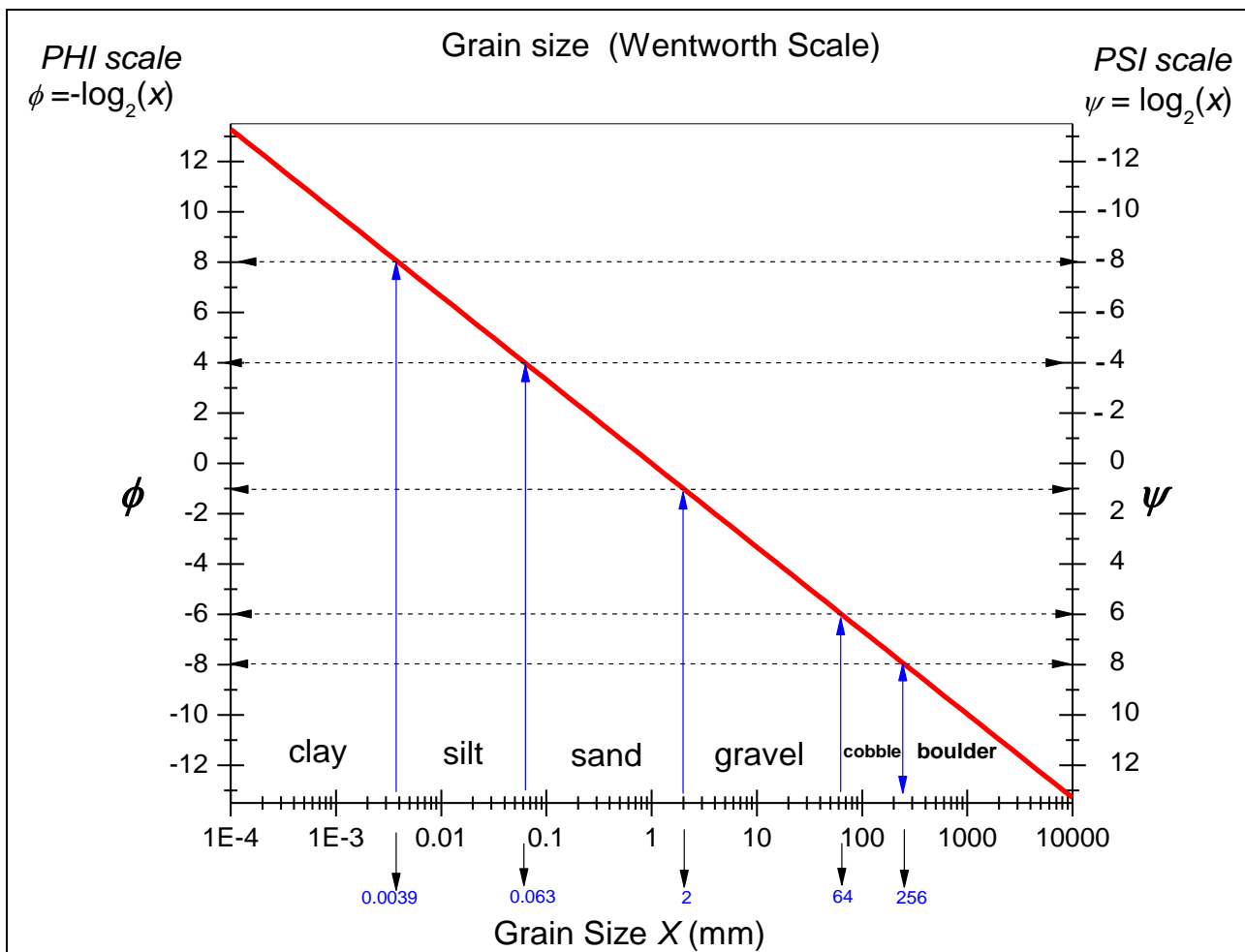
Are useful the following approximate expressions for direct and inverse computation:

$$\phi = -3.3219 \log_{10} X \quad [3]$$

$$\psi = 3.3219 \log_{10} X \quad [4]$$

$$X = 10^{-0.301\phi} \quad [5]$$

$$X = 10^{0.301\psi} \quad [6]$$



**Fig. 1 : sedimentological grain size scale (Wentworth scale) and particle size class limits**

#### 4-The lognormal distribution –adopted until version DECOLOG release 2.2 included

The lognormal distribution is of importance in the earth sciences (Limpert et al. 2001). Examples include:

- The  $\phi$ -fraction in sedimentology which is defined from the lognormal distribution. Let  $\mathbf{X}$  be grain diameter in mm and let  $\phi = -\log_2 X$  (Wentworth PHI scale)
- This choice is based on the empirical observation that  $\mathbf{X}$  is lognormal.
- Sedimentary bed thickness
- Permeability and pore size
- Concentration of trace elements in rocks
- The magnitude of earthquakes (viz., the Richter scale is logarithmic)
- The lognormal distribution is not symmetric-it falls to zero quickly and to  $\infty$  slowly

Three parameters general form for right tailed lognormal distribution is adopted. The lognormal distribution is defined by three parameters (Aitchison and Brown, 1957; Crow and Shimizu, 1988):

$\lambda$  : the location/shift parameters related to the shifting on i axis with respect the origin of the axis.  
 $\alpha$  : the scale parameter that is function of the arithmetic mean of the population  
 $\beta$  : the shape parameter that is function of the standard deviation of the population

**4.1- The probability density function (PDF) given for any x:**

for  $x \leq \lambda$  :  $f(x) = 0$  [7]

for  $x > \lambda$  : 
$$f(x) = \frac{e^{-\frac{(\ln(x-\lambda)-\alpha)^2}{2\beta^2}}}{\sqrt{2\pi}\beta(x-\lambda)}$$
 [8]

**4.2-The cumulative distribution function (CDF) given for any x**

for  $x \leq \lambda$   $F(x) = 0$  [9]

for  $x > \lambda$  : 
$$F(x) = \frac{1}{2} \left( 1 + \operatorname{erf} \left( \frac{\ln(x-\lambda)-\alpha}{\beta\sqrt{2}} \right) \right)$$
 [10]

where *erf* is the well know error function.

**5-The lognormal distribution –adopted in the DECOLOG release 3.0**

The release 3.0 adopt an important generalisation of the lognormal distribution. In this generalisation we adopt the possibility to adopt also **negative skewness, left tail, lognormal distributions**. This is the possibility was identified firstly by Aitchison and Brown (1957).

The generalised form has four parameters:

$k$  : The value  $k= +1$  produces a classical (right tailed – positive skewness), the value  $k= -1$  produces (left tailed – negative skewness)  
 $\lambda$  : the location/shift parameters related to the shifting on i axis with respect the origin of the axis.  
 $\alpha$  : the scale parameter that is function of the arithmetic mean of the population  
 $\beta$  : the shape parameter that is function of the standard deviation of the population

The possibility to adopt lognormal distribution with negative skewness allows the version 3.0 to work in both the PHI and PSI grain size scale. Any way the standard PHI scale is preferred.

### 5.1 -the probability density function (PDF) given for any $x$

For  $k= - 1$  the left tailed lognormal the probability density function (PDF) is given for any  $x$  :

$$\text{for } x \leq \lambda : \quad f(x) = \frac{e^{-\frac{(\ln(k(x-\lambda))-\alpha)^2}{2\beta^2}}}{\sqrt{2\pi}\beta(k(x-\lambda))} \quad [11a]$$

$$\text{for } x > \lambda : \quad f(x) = 0 \quad [11b]$$

For  $k= + 1$  the right tailed lognormal the probability density function (PDF) is given for any  $x$

$$\text{for } x \leq \lambda : \quad f(x) = 0 \quad [12a]$$

$$\text{for } x > \lambda : \quad f(x) = \frac{e^{-\frac{(\ln(k(x-\lambda))-\alpha)^2}{2\beta^2}}}{\sqrt{2\pi}\beta(k(x-\lambda))} \quad [12b]$$

### 5.2 -The cumulative distribution function (CDF) given for any $x$

For  $k= - 1$  the left tailed lognormal CDF is :

$$\text{for } x \leq \lambda \quad F(x) = \frac{1}{2} \left( 1 + \operatorname{erf} \left( \frac{k(\ln(k(x-\lambda))-\alpha)}{\beta\sqrt{2}} \right) \right) \quad [13a]$$

$$\text{for } x > \lambda : \quad F(x) = 1 \quad [13b]$$

For  $k= + 1$  the right tailed lognormal CDF is :

$$\text{for } x \leq \lambda \quad F(x) = 0 \quad [14a]$$

$$\text{for } x > \lambda : \quad F(x) = \frac{1}{2} \left( 1 + \operatorname{erf} \left( \frac{k(\ln(k(x-\lambda))-\alpha)}{\beta\sqrt{2}} \right) \right) \quad [14b]$$

where *erf* is the well know *error function*.

## 6-The statistical parameters from a lognormal population

In the generalised form the values of relevant statistical parameters of the population represented by the lognormal distribution defined from the above PDFs and CDFs are :

$$mode = \lambda + ke^{(\alpha-\beta^2)} \quad [15]$$

$$median = \lambda + ke^\alpha \quad [16]$$

$$mean = \lambda + ke^{\left(\frac{\alpha+\beta^2}{2}\right)} \quad [17]$$

$$variance = e^{(2\alpha+\beta^2)} \left[ e^{(\beta^2)} - 1 \right] \quad [18]$$

$$standard\ deviation = \sqrt{e^{(2\alpha+\beta^2)} \left[ e^{(\beta^2)} - 1 \right]} \quad [19]$$

$$skewness = k \left( e^{\beta^2} + 2 \right) \sqrt{e^{\beta^2} - 1} \quad [20]$$

$$kurtosis = e^{(4\beta^2)} + 2e^{(3\beta^2)} + 3e^{(2\beta^2)} - 6 \quad [21]$$

Please note that for standard 3 parameters lognormal distribution (right tailed) we must always use  $K=+1$ . !

### 6-The mixture of lognormal distribution

The lognormal distribution can be used to generate mixture of more components as other distribution. In general way the mixture of lognormal distribution is defined bay the following expression for the PDF and CDF :

$$f(x)_{mix} = w_1 f_1(x) + w_2 f_2(x) + \dots + w_n f_n(x) \quad [22]$$

$$F(x)_{mix} = w_1 F_1(x) + w_2 F_2(x) + \dots + w_n F_n(x) \quad [23]$$

Where  $w_i$  are the weights of each component of the mixture that represents their relative importance and obey to the following constraint:

$$\sum_{i=1}^n w_i = 1 \quad [24]$$

In the DECOLOG we **limited at 3 the maximum number of components of the mixture**

## 8-Input data

The input data are characterized by a ASCII text files that contains in the first column the PHI value class corresponding grain size dimension in the PHI scale and in the second column the relative frequency of the corresponding PHI class and expressed as fraction. The sum of the values in the second column is 1. The program computes automatically the CDF as cumulative value of the second column. See the example below.

### IMPORTANT! (To avoid strange and not reliable result:)

- **Please note: it is important that the sum of the fractions in the second column must be equal to 1.0!**
- **Please note: for a better optimization is important that at least two 0 fraction corresponding to lower PHI and highest PHI be present (see data file example above)**
- **Please note: decimal PHI values are allowed**
- **Please note: uneven spacing between PHI values are allowed**
- **Please: be sure that your PC are using the dot as decimal separator before to load the compatible .XLS file in Microsoft office EXCEL**

The sum of the values in the second column is 1. The program computes automatically the CDF as cumulative value of the second column. See the example below.

The first type of data processing procedure uses as input a single data file as the following example:

-12	0
-11	0
-10	0.00499
-9	0.01497
-8	0.03992
-7	0.13473
-6	0.20459
-5	0.20459
-4	0.15469
-3	0.06367
-2	0.04042
-1	0.03447
0	0.03468
1	0.02992
2	0.02118
3	0.00944
4	0.00315
5	0.0022
6	0.00119
7	0.00062
8	0.00056
9	0
10	0

## 9-More than one file to be process

In case of more files to be processed the user may activate the batch processing procedure. To do this you must assemble a list of names of files to be processed. An example is given as follow;. Please note that the list is saved in a ASCII text file with extension .TXT:

*Colsa1.dat*



*Colsa1b.dat**Colsa2a.dat**Colsa3.dat*

.....

.....

The file that contains the list to be processed is loaded by the processing procedure 2. Each file in the list is processed sequentially and as output a new filename, with extension XLS is saved on hard disk in the same location of the input files.

## 10-Decoding with non linear multi-objective global optimization

A non linear multiobjective global optimization procedure has been developed to complete in efficient and robust way the decoding process. The optimization process allow to obtain the parameters  $k_i, \alpha_i, \beta_i, \lambda_i, w_i$  for each distribution. The common ways to fit sample/observed distribution with a theoretical one is the fitting the observed PDF or alternatively using the observed CDF (Macdonald PDM, Green PEJ (1998),).

The fitting of the PDF of the CDF pose different problems. For example the two form or represent the distribution has a different mathematical and analytical significance. The PDF is the first derivative of the CDF form. This fact implies that during the fitting the small peaks in the PDF may be traduced in erroneous influence in peaks guessing. This problem has a different role in CDF because the local pecks are identified mainly as local increase of slope. In the CDF small peaks may be obliterate from the cumulative process when we have high function value. Limiting the fitting to the PDF alone we can observe always that the successive comparison of the derived CDF with the observed may have poor performances.

This problem has been overcome in DECOLOG using a heuristic procedure. We established a concurrent fitting of the PDF and CDF observed by way of a multi-objective optimization minimizing at the same time the errors in the PDF and CDF. Because the tho objective are concurrent each optimum may be partially in conflict with the other establishing dominance. So to obtain a result we transform the multi-obective process for a computation purpose in a single objective optimization. Do realize this we use the methodology described by (Anderson, 2000 ) or use as objective function a weighted sum of single objective functions relative to each concurrent process. Each objective function must have a common range of variation (e.g.[0.0,1.0]) and the weights must be chosen in a way that de dominance of each objective is reduced.

Our final single objective function is the following:

$$\min [W_{CDF} K + W_{PDF} (1 - E_{ff})] \quad [25]$$

And where:

$$W_{CDF} + W_{PDF} = 1 \quad [26]$$

Where  $K$  is the Kolmogorov-Smirnov parameters (Chakravarti 1967) or the maximum difference, ranging between 0.0 and 1.0, between the observed and computed CDF in the same observed points.

$E_{ff}$  is the model efficiency parameter developed by Nash and Sutcliffe (1970) that has a well recognised performances for non linear fitting. These parameters vary between 1.0 (perfect fitting) and  $-\infty$  (worst fitting).

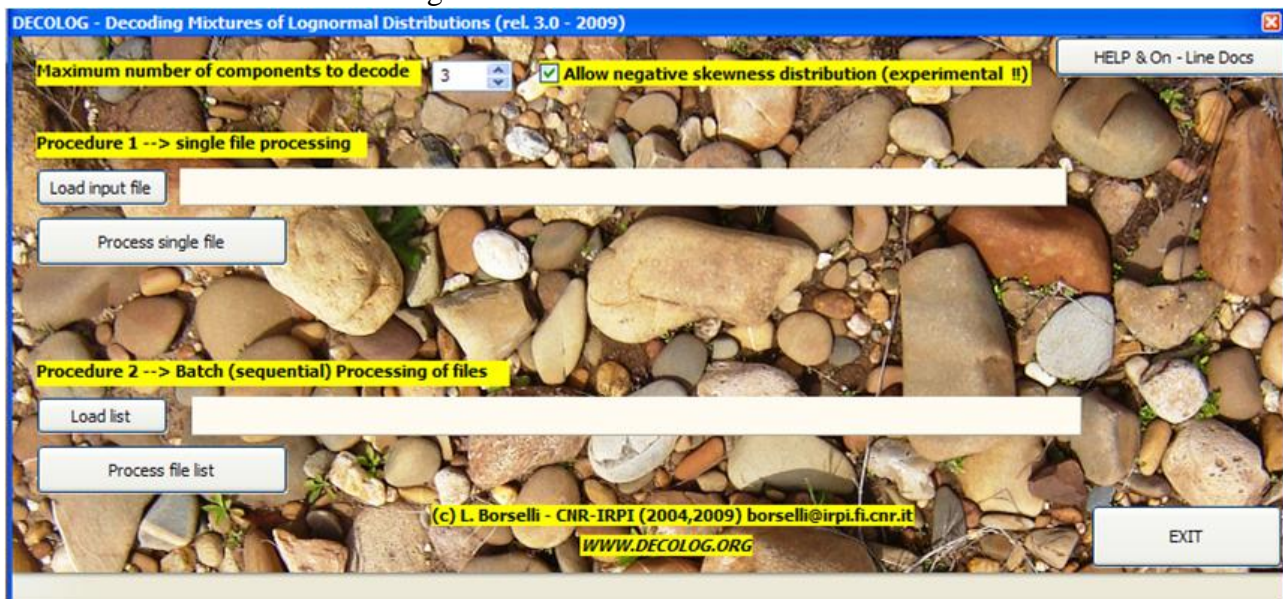
$W_{CDF}, W_{PDF}$  are tow weights that are identified with numerous tests allow to reduce greatly the dominance of each single objective balancing at runtime the different efficiency in the fitting of the PDF and the CDF.

In the case of 3 components we have a maximum of 11 parameter to optimize. In this case the large number of parameters to optimize requires an adequate degree of freedom, so an adequate number of data points in the distribution observed.

The global optimization algorithm is based on Differential evolution (DE) (Storn and Price ,1997a,1997b; Storn 1999). The DECOLOG code has been implemented in Object Pascal programming language and FPC compiler rel 2.2.4 ([www.freepascal.org](http://www.freepascal.org)).

## 11-DECOLOG User Interface

DECOLOG has a simple user interface to active the two type of processing procedure. The main interface is shown in fig. 1.



**Fig. 2: main interface of DECOLOG. 3.0**

A click LOAD INPUT FILE button will open a file dialog that asks for a single input file. Then we can process this file pressing the button POCCESS SINGLE FILE.

Before the processing the program asks a confirmation that a XLS file will be written at the end of the processing. Alternatively the user can indicate a different filename.

The number of component to decode may be varied by the user.. an input cell at the top of the window allow to vary the number (1, 2 or 3).

In the DECOLOG 3.0 the user can check or uncheck the **option to allow negative skewness distributions**.

If this option is **Unchecked**, will be run the basic **optimization engine of the updated version 2.1** (fig. 2). In this case only distribution with positive skewness (right tail) are allowed.

If this option is **Checked**, will be run the **new optimization engine of the version 3.0** (fig. 3). In this case distribution with positive skewness (right tail) and negative skewness (left tailed) are allowed.

The procedure 2 is similar to procedure 1 . After pressing the LOAD LIST button the program ask the file .TXT that contains the list of name of files to be processed.

Pressing the POCCESS FILE LIST will activate the sequential processing of the list.

Every time an input file is processed a monitor of the optimization process will be activated. The full optimization process is continuously updated. The user can break the current process pressing the ESC key.. at the end it is required press ENTER to exit from the console and back to main window of the program in fig. 1.

```

D:\LAVORI\DAMIANO\decolog\lazarus\decolog21process.exe
-----DECOLOG (rel. 2.1 - 2004,09) by L. Borselli CNR-IRPI Florence<Italy>-----
----- An Alternative to "SFT" -----
-- MULTI-OBJECTIVES OPTIMIZATION ROUTINE BY DIFFERENTIAL EVOLUTION ALGORITHMS --
Current input file: D:\LAVORI\DAMIANO\decolog\lazarus\colsala.dat
Current output file: D:\LAVORI\DAMIANO\decolog\lazarus\colsala.XLS
- press [Esc] to force termination of current parameters optimization -

  Functions evaluated          Func. Value          DELTA
  524445                      0.030481024         0.004972211

Log_Components-> 1st                2nd                3th
Shift  -1.1468E+001  Shift  -1.1149E+001  Shift  -4.3713E+000
Scale   1.8113E+000  Scale   1.3656E+000  Scale   1.5994E+000
Shape   2.5670E-001  Shape   5.5888E-001  Shape   2.9815E-001
Fract   7.6455E-001  Fract   1.4029E-001  Fract   9.5161E-002

Optimization process completed with success! - [press a ENTER to exit] -
    
```

Fig. 3: example optimization process monitor in DECOLOG. 2.1 obtained deactivating the option to allow negative skewness distribution

```

D:\LAVORI\DAMIANO\decolog\lazarus\decolog30process.exe
-----DECOLOG (rel. 3.0 - 2004,09) by L. Borselli CNR-IRPI Florence<Italy>-----
----- An Alternative to "SFT" -----
-- MULTI-OBJECTIVES OPTIMIZATION ROUTINE BY DIFFERENTIAL EVOLUTION ALGORITHMS --
Current input file: D:\LAVORI\DAMIANO\decolog\lazarus\colsala.dat
Current output file: D:\LAVORI\DAMIANO\decolog\lazarus\colsala.XLS
- press [Esc] to force termination of current parameters optimization -

  Functions evaluated          Minimized Func. Value          DELTA
  4605109                    0.028025542         0.004350849

Log_Components-> 1st                2nd                3th
K      +1          K      +1          K      -1
Shift  -8.9512E+000  Shift  -8.1458E+000  Shift  2.0909E+000
Scale   1.0446E+000  Scale   2.0743E+000  Scale   2.0240E+000
Shape   4.2942E-001  Shape   2.2699E-001  Shape   2.1759E-001
Fract   2.2312E-001  Fract   1.4579E-001  Fract   6.3109E-001

Optimization process completed with success! - [press a ENTER to exit] -
    
```

Fig. 4: example optimization process monitor in DECOLOG. 3.0 obtained activating the option to allow negative skewness distribution

## 12-The Decolog Output

The decolog write the output in XLS compatible files. Usually the output file has the same name of the input file but with the XLS extension..

Double click on the XLS files allow to Microsoft EXCEL to open it after a fast and automatic conversion. The output file is an ASCII text file, but the data are separated by TAB character. These characteristics allow this file to be load automatically by MICROSOFT EXCEL. Finally the file can be saved with internal binary format XLS or XLSX of Microsoft office excel (97-2003 or 2007)

Some tables extracted by an output file and graphs produced in Microsoft EXCEL are shown as follow (this example is related to results of the DECOLOG 3.0 new optimization engine):

Table 1: fitting coefficients for the three decoded distribution

----- OPTIMUM FITTING PARAMETERS -----		
k 1	:	<b>1</b>
k 2	:	<b>1</b>
k 3	:	<b>-1</b>
Shift1 (lambda):		<b>-9.3212</b>
Shift2 (lambda):		<b>-8.6731</b>
Shift3 (lambda):		<b>1.6709</b>
Scale1 (alpha):		<b>1.1303</b>
Scale2 (alpha):		<b>2.1158</b>
Scale3 (alpha):		<b>1.966</b>
Shape1 (beta):		<b>0.3529</b>
Shape2 (beta):		<b>0.2231</b>
Shape3 (beta):		<b>0.2275</b>
Fraction 1	:	<b>0.2013</b>
Fraction 2	:	<b>0.1555</b>
Fraction 3	:	<b>0.6432</b>
-----		
Total minimized Objective function value:		<b>0.028</b>

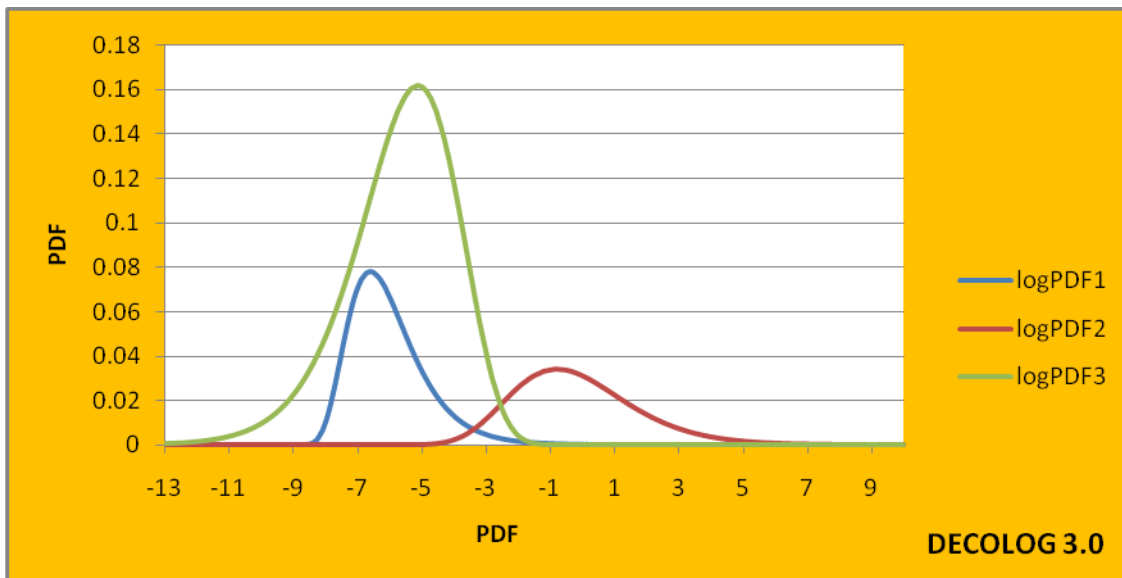


Fig.5: 3 components of decoded distribution using DECOLOG.

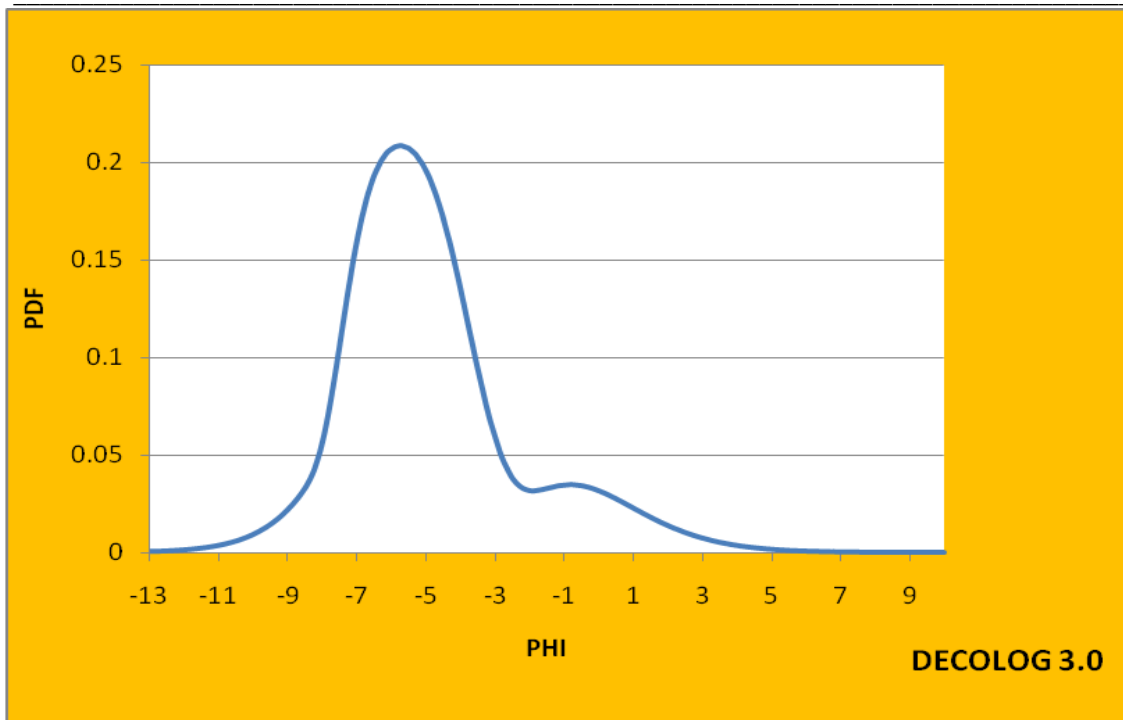


Fig 6.: sum of the decoded distribution components.

**Table 2: goodness of fitting parameters or PDF:**

Global fitting statistics for PDF -----

<b>Model efficiency coefficient EF :</b>	<b>0.9812011</b>
<b>Coefficient of Determination R<sup>2</sup> :</b>	<b>0.9905694</b>

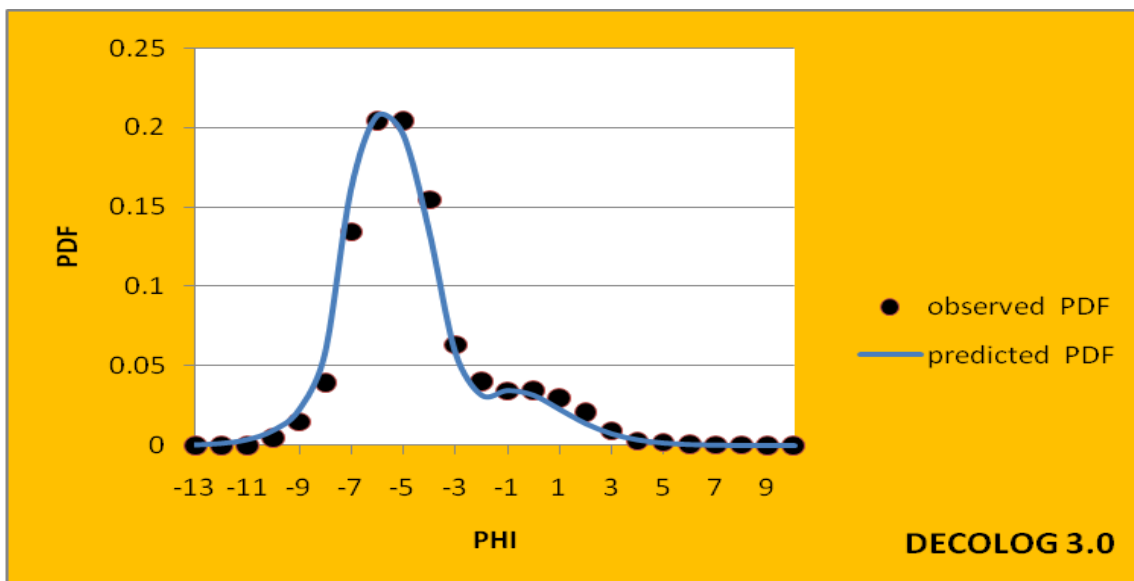


Fig 7.: global fitting performance on the observed PDF

**Table 3: goodness of fitting parameters or CDF:**

Global fitting statistics for CDF -----

<b>Model efficiency coefficient EF :</b>	<b>0.9988534</b>
--	------------------

Coefficient of Determination  $R^2$  : 0.99949  
 Kolmogorov-Smirnoff difference  $K_s$  : 0.0403887

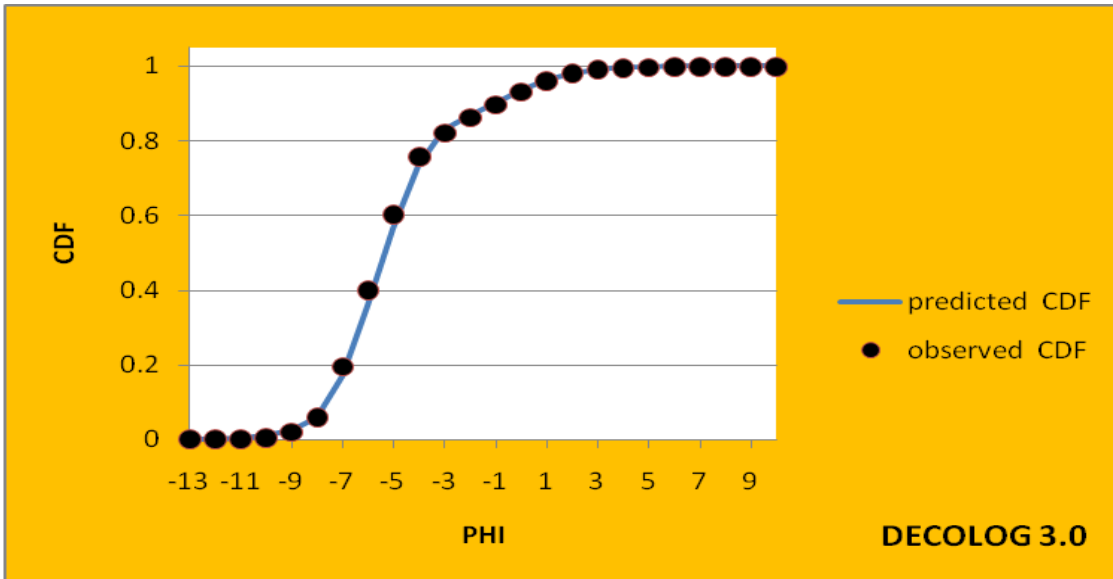


Fig 8.: global fitting performance on the observed CDF

Table 4: statistical parameters of the distributions and mixture

-----**STATISTICAL PARAMETERS OF THE DISTRIBUTIONS AND MIXTURE---**

FIRST LOGNORMAL	
Mean :	-6.0257
Mode :	-6.5873
Median :	-6.2247
Variance :	1.4406
Standard deviation :	1.2003
Skewness :	1.1409
Kurtosis :	2.4007
SECOND LOGNORMAL	
Mean :	-0.1678
Mode :	-0.7797
Median :	-0.3769
Variance :	3.6921
Standard deviation :	1.9215
Skewness :	0.6893
Kurtosis :	0.8565
THIRDDTH LOGNORMAL	
Mean :	-5.6584
Mode :	-5.1111
Median :	-5.4712
Variance :	2.8522
Standard deviation :	1.6888
Skewness :	-0.7035
Kurtosis :	0.8927

Table 5: GLOBAL STATISTICS FROM WEIGTHED COMPONENTS OF THE DERIVED MIXTURE

Mean :	-
--------	---



	4.8785
Standard deviation :	2.6088
Skewness:	0.9828
Kurtosis :	4.089

Table 6: Folk Ward statistics derived by linear interpolation of the observed CDF

mean	-5.10763
std dev	2.51669
skewness	0.31827
kurtosis	1.35744
Relevant quantiles:	
q=0.05	-8.24751
q=0.10	-7.70223
q=0.16	-7.2569
q=0.25	-6.72928
q=0.50	-5.50734
q=0.75	-4.05488
q=0.84	-2.55865
q=0.90	-0.91499
q=0.95	0.61053

Table 7: computed statistics by resample observed empirical CDF with monte-carlo techniques (20.000 random resampled values)

mean	-4.98075
std dev	2.63142
skewness	1.08773
kurtosis	4.26684

### 13-Installation of DECOLOG 3.0.

To install the software simply uncompress the .ZIP files that contain the package in a directory of your PC. The installation package can be downloaded to the web page:

[http://www.decolog.org/decolog\\_install\\_file.zip](http://www.decolog.org/decolog_install_file.zip)

### 14-References

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