PARFIT-2.4.1

A tool for the parametrization of volcanic ash deposits

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Date: October 27, 2026

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1 Introduction

A common problem in volcanology is the description of the volcanic column and the ash transport mechanisms starting from the deposit generated by the eruption itself. Different models are available for solving the direct problem, that is to estimate the ash fall deposit starting from the total erupted mass, grain size distribution of the particles, wind field, atmospheric conditions, volcanic column height and shape (eg: FALL3D, HAZMAP, TEPHRA, etc.), however few methods are available for solving the inverse problem (eg: Pyle, 1989; Bonadonna et al., 1998). PARFIT belongs to the category of the solvers of this inverse problem, whose aim is to find the set of input parameters that minimize the difference between the simulated and the real deposits. PARFIT was designed for searching the best parameters (total mass, column height, the bulk granulometry, the mass distribution inside the column, wind profile and atmospheric diffusion coefficient), required by the computer code HAZMAP, for reconstructing the observed tephra deposits and granulometry spectra. However, the obtained results can be used also as input to other models. Recently, PARFIT was applied for the reconstruction of ash fall deposits the Plinian eruption of Vesuvius occurred in A.D. 472 (Bonasia et al., 2010). The first version of PARFIT was developed by G. Macedonio, R. Bonasia and A. Costa at the Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Vesuviano, Napoli (Italy), in the ambit of the Project SPeeD, funded by the Department of the Civil Protection, Project V5, INGV-DPC Agreement 2007-2009.

2 Description of PARFIT

PARFIT is a FORTRAN code able to find the volcanic eruption parameters, starting from field data. On UNIX/Linux machines, PARFIT is executed by invoking the command `parfit` from the shell prompt. The code reads the control file (`parfit.inp`) where the user defines the domain of investigation of the eruption parameters and other computational flags (see Sec. 3.1), then it loads the thickness of the ground deposit measured in different stratigraphic sections (file `ground_thickness.inp`), and performs a search on grid for finding the best parameters that fit the deposit using the model HAZMAP (Macedonio et al., 2005; Pfeiffer et al., 2005). If the bulk grain size distribution (ie: the grain size distribution in the eruption column) is known, it may be specified in the optional input file `column_spectrum.inp`. Alternatively, the bulk grain size distribution is estimated by `parfit` starting from the size distributions at ground, defined in file `ground_spectra.inp`. Results are printed on the screen and in file `parfit.out`).

2.1 How PARFIT works

Input parameters required by HAZMAP for reconstructing an ash fallout deposit produced by an explosive volcanic eruption can be obtained solving an inverse problem.
Fitting is performed using a least-squares method which compares measured and calculated deposits thickness and grain-sizes. Because of the inherent limitation of the model to medium-range and distal parts of a deposit, only available data at a distance of at least few km from the eruption vent are considered.
The function to be minimised (e.g Pfeiffer et al., 2005; Costa et al., 2009) is:

$$\chi^2 = \frac{1}{N-p} \sum_{i=1}^{N} w_i [Y_{obs,i} - Y_{mod,i}]^2 \tag{1}$$

where w_i are weighting factors, N is the number of observed data, p is the number of free parameters, $Y_{obs,i}$ denote the observed ground load (kg/m^2) and $Y_{mod,i}$ the values predicted by the model. The choice of the weighting factors, w_i, depends upon the distribution of the errors (Costa et al., 2009).
In order to well constrain the input parameters, it is necessary to know thickness and grain-size values in a large number, N, of stratigraphic sections, such as $N \gg p$. For example, Pfeiffer and Costa (2004) showed that a good reliable inversion is given by at least 40-50 well distributed stratigraphic sections and at least 3-5 sections with individual granulometry and particle component distributions. However, especially for ancient eruptions, finding enough outcrops with a good exposure is often very arduous.

There is a risk of finding parameters that result physically incorrect, especially when we deal with portions of the deposit, which represent the tail of the distribution relative to a particle class. In order to avoid these problems, in the scientific literature, other techniques for the calculation of the particles spectrum, in terms of the total grain-size distribution, were adopted, allowing the reduction of the degrees of freedom. PARFIT-2.4.1 uses a new procedure which allows for fitting also the bulk grain-size distributions, even when only few stratigraphic sections are available.
We assume that the best-fitted parameters such as column height, column shape coefficients, wind velocity and diffusion coefficient, do not vary with the choice of the grain-size classes. Thus, among all the possible choices, we focus on a restricted number of grain-size classes, for which the inverse problem results better constrained. In fact, in a first step, the program identifies the area enclosed by the measured ground sections, that is delimited by a "convex hull". The calculation of the total mass at the ground is performed by summing the contribution of each particle type that leads to a Gaussian centre placed inside the "convex hull" of the measured ground-sections. This procedure allows for estimating the total mass relative to these classes only. In order to obtain the total mass over a wider range of grain-sizes, in a second step, we repeat the inversions fixing the values of column height, wind direction, wind speed and diffusion coefficients, as they were obtained in the previous step, and extend the computation of the bulk particle spectrum to the particles classes previously neglected, thus, leading to the final estimation of the effective total mass and of the total bulk velocity class distribution.
The ash load at the ground is given by:

$$M(x,y) = \sum_{i,j} \frac{M_i f_j}{2\pi\sigma_{i,j}^2} \exp\left[-\frac{(x-x_{Gi})^2 + (y-y_{Gi})^2}{2\sigma_{i,j}^2}\right] \tag{2}$$

where $\sigma_{i,j}^2$ is the thickness of the Gaussian relative to the particles that fall from the height z_i with the settling velocity v_j. It is related to the settling time and the diffusion coefficient by the relation: $\sigma_{i,j}^2 = 2Kt_{i,j}$.
The particles settling velocity varies with the height.
In order to take into account the variability of the particles velocity with height, it is defined the coefficient:

$$b(i,j) = \frac{1}{4t_{i,j}} = \frac{1}{4\sum_{k\leq i}} \frac{dz_k}{v_{k,j}} \tag{3}$$

where $dz_{i,j}$ is the thickness of the layer k and $v_{k,j}$ the settling velocity of the particle of the class j into the layer k. The ground load is, then, given by:

$$M(x,y) = \sum_{i,j} \frac{M_i f_j b_{i,j}}{\pi K} \exp\left[-\frac{b_{i,j}}{K}[(x-x_{Gi})^2 + (y-y_{Gi})^2]\right] \tag{4}$$

The mass distribution in real eruption columns is governed by complex physical processes that the model cannot account for. In order to consider a mushroom-like shape for the column, it is used an empirical formula modified from the original Suzuki formula (Suzuki, 1983):

$$S(x,y,z,t) = S_0 \left\{(1-\frac{z}{H})\exp[A(\frac{z}{H}-1)]\right\}^{\lambda} \times \delta(t-t_0)\delta(x-x_0)\delta(y-y_0) \tag{5}$$

where S_0 is the normalisation constant, x_0, y_0 are the coordinates of the vent, H is the column height and A and λ are two empirical parameters introduced in Pfeiffer et al. (2005).
The user defines the range and step of the eruption parameters. This defines a multidimensional grid generated by all the combinations of the parameters. PARFIT performs a search on the grid for the minimum χ^2 between the simulated deposit simulated and the field data. Simulations are performed using the HAZMAP model (embedded in PARFIT). is based on HAZMAP, a computer program for simulating the ground deposit generated by the sedimentation of volcanic particles from an explosive eruption (Macedonio et al., 2005; Pfeiffer et al., 2005).

3 Input files

3.1 The input file `parfit.inp`

File `parfit.inp` contains information for performing the search of the eruptions parameters and for controlling the output generated by PARFIT. This file is structured in blocks following the FORTRAN NAMELISTs, easily readable from FORTRAN codes. These blocks are: WIND, TURBULENCE, COLUMN, VENT, FLAGS and FILES. Each block begins with the directive `&block_name` and ends with a slash "/", where `block_name` is the name of the block. The blocks can be specified in any order. Each block contains a list of variables with associated their value. Comments start with the symbol "!" and are ignored. The name of the variables reflect the same name of the variable used in the FORTRAN code. A sample of this file is reported in Table 1.

3.1.1 Block WIND

This is the first block of file `parfit.inp`. It begins with the directive `&WIND` and ends with a slash: "/" (see also Table 1). In this block, data referring to the generated wind profile are specified. The user may specify a single wind profile read from a file or specify some parameters used to generate a sequence of wind profiles for best fitting the deposit data.

- `rwindfile`
  This flag selects whether the wind profiles are read from a file `wind.dat` (flag `rwindfile = 1`) or the wind profiles are generated using the other parameters defined below (flag `rwindfile = 0`). With flag `rwindfile = 1` the parameters `wndmin`, `wndmax`, `wndstep`, `dirmin`, `dirmax` and `dirstep` are not used. The structure of file `wind.dat` is specified in Sec. 3.5.

- `htropo`
  This parameter is used when flag `rwindfile=0` and specifies the height of the tropopause (in meters). In PARFIT, `htropo` coincides with the height where the wind has its maximum intensity. Fig. 1) shows the wind profile generated by PARFIT. According to Cornell et al. (1983), we assume that the wind speed increases from zero at sea level, up to its maximum at the height of the tropopause (parameter `htropo`), then its value is 75% of its maximum value. The wind profile is then multiplied by the the factor `wnd` and rotated along the vertical axis, towards direction `dir` (see (6) and (8)).

- `wndmin`
  This parameter defines the minimum value of the wind intensity at tropopause (in m/s). The generated wind intensity values start from `wndmin` and increase by `wndstep` up to `wndmax`. This parameter is used only with flag `rwindfile=0`.

- `wndmax`
  This parameter defines the maximum value of the wind intensity at tropopause (in m/s). The generated wind intensity values start from `wndmin` and increase by `wndstep` up to `wndmax`. If `wndmin` is equal to `wndmax`, then only one wind intensity is generated. This parameter is used only with flag `rwindfile=0`.

- `wndstep`
  This parameter defines the increase step of the wind intensity at tropopause (in m/s). The generated wind intensity values start from `wndmin` and increase by `wndstep` up to `wndmax`. The value of `wndstep` should be equal to the difference (`wndmax` - `wndmin`) divided by an integer number (the number of steps -1). The generated sequence of wind intensities at tropopause (`wnd`) is:

$$\texttt{wnd}_i = \texttt{wndmin} + i * \texttt{wndstep} \qquad (i = 0, ..., \texttt{nwnd}) \tag{6}$$

  where `nwnd` is the number of generated wind directions: This parameter is used only with flag `rwindfile=0`.

$$\texttt{nwnd} = \text{NINT}\left(\frac{\texttt{wndmax} - \texttt{wndmin}}{\texttt{wndstep}}\right) \tag{7}$$

  and NINT represents the nearest integer.

- `dirmin`
  This parameter defines the minimum value of the wind direction at tropopause (in degrees_east). The generated wind direction values start from `dirmin` and increase by `dirstep` up to `dirmax`. The wind direction is the direction towards the wind blows; it starts from East (direction=0) and increases counter-clockwise (eg: a wind blowing from South has direction=90, and a wind from East has direction=180). This parameter is used only with flag `rwindfile=0`.

- `dirmax`
  This parameter defines the maximum value of the wind direction at tropopause (in degrees_east). The generated wind direction values start from `dirmin` and increase by `dirstep` up to `dirmax`. If `dirmin` is equal to `dirmax`, then only one wind direction is generated. This parameter is used only with flag `rwindfile=0`.

- `dirstep`
  This parameter defines the increase step of the wind direction at tropopause (in degrees). The generated wind direction values start from `dirmin` and increase by `dirstep` up to `dirmax`. The value of `dirstep` should be equal to the difference (`dirmax` - `dirmin`) divided by an integer number (the number of steps -1). The generated sequence of wind directions (`dir`) is:

$$\texttt{dir}_i = \texttt{dirmin} + i * \texttt{dirstep} \qquad (i = 0, ..., \texttt{ndir}) \tag{8}$$

  where `ndir` is the number of generated wind directions:

$$\texttt{ndir} = \text{NINT}\left(\frac{\texttt{dirmax} - \texttt{dirmin}}{\texttt{dirstep}}\right) \tag{9}$$

  and NINT represents the nearest integer. This parameter is used only with flag `rwindfile=0`.

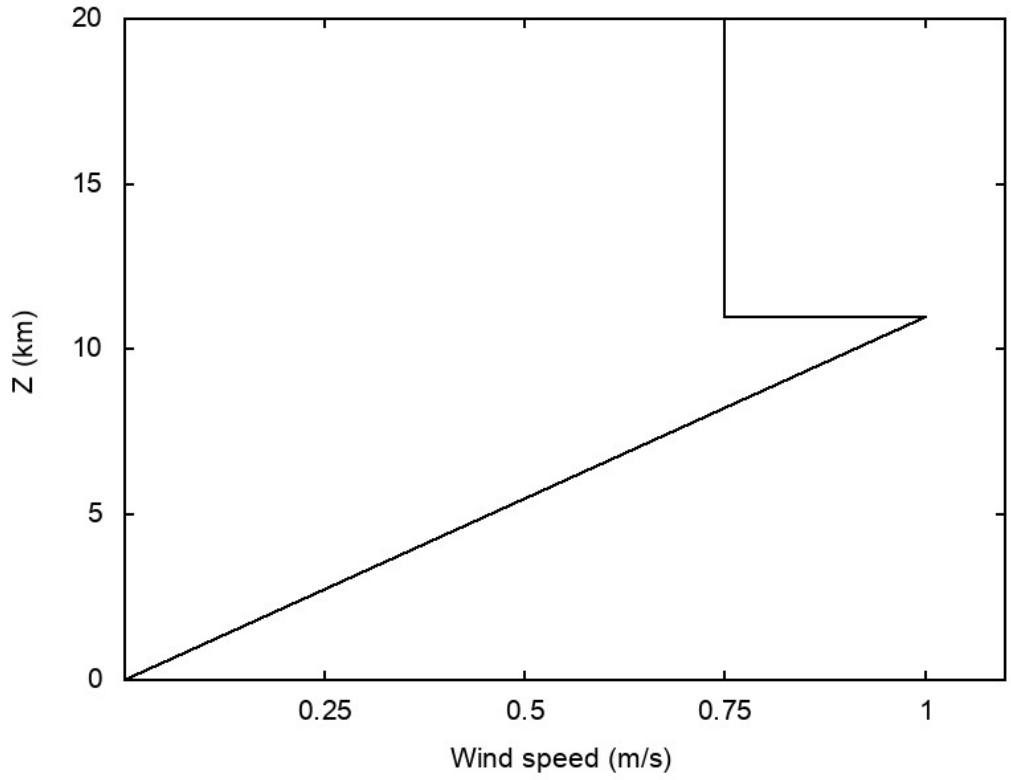


Figure 1: Wind profile generated by PARFIT.

3.1.2 Block TURBULENCE

- `cdmin`
  This parameter defines the minimum value of the atmospheric diffusion coefficient (in m^2/s). The generated atmospheric diffusion coefficient starts from `cdmin` and increase by `cdstep` up to `cdmax`. The wind direction is the direction towards the wind blows; it starts from East (direction=0) and increases counter-clockwise (eg: a wind blowing from South has direction=90, and a wind from East has direction=180).

- `cdmax`
  This parameter defines the maximum value of the atmospheric diffusion coefficient (in m^2/s). The generated wind direction values start from `cdmin` and increase by `cdstep` up to `cdmax`. If `cdmin` is equal to `cdmax`, then only one wind direction is generated.

- `cdstep`
  This parameter defines the increase step of the atmospheric diffusion coefficient (in m^2/s). The generated diffusion coefficient start from `cdmin` and increase by `cdstep` up to `cdmax`. The value of `cdstep` should be equal to the difference (`cdmax` - `cdmin`) divided by an integer number.

  The generated sequence of atmospheric diffusion coefficients (`cd`) is:

$$\texttt{cd}_i = \texttt{cdmin} + i * \texttt{cdstep} \qquad (i = 0, ..., \texttt{ncd}) \tag{10}$$

  where `ncd` is the number of generated wind directions:

$$\texttt{ncd} = \text{NINT}\left(\frac{\texttt{cdmax} - \texttt{cdmin}}{\texttt{cdstep}}\right) \tag{11}$$

  and NINT represents the nearest integer.

3.1.3 Block COLUMN

- `hcolmin`
  This parameter defines the minimum value of the volcanic column height (in meters). The generated column height start from `hcolmin` and increase by `hcolstep` up to `hcolmax`. The column height is the height of the top of the column respect to the sea level.

- `hcolmax`
  This parameter defines the maximum value of the volcanic column height (in meters). The generated column heights start from `hcolmin` and increase by `hcolstep` up to `hcolmax`. If `hcolmin` is equal to `hcolmax`, then only one column height is generated. The column height is the height of the top of the column respect to the sea level.

- `hcolstep`
  This parameter defines the increase step of the eruptive column height (in meters). The generated column heights start from `hcolmin` and increase by `hcolstep` up to `colmax`. The value of `hcolstep` should be equal to the difference (`hcolmax` - `hcolmin`) divided by an integer number.

  The generated sequence of volcanic column heights (`hcol`) is:

$$\texttt{hcol}_i = \texttt{hcolmin} + i * \texttt{hcolstep} \qquad (i = 0, ..., \texttt{nhcol}) \tag{12}$$

  where `nhcol` is the number of generated column heights:

$$\texttt{nhcol} = \text{NINT}\left(\frac{\texttt{hcolmax} - \texttt{hcolmin}}{\texttt{hcolstep}}\right) \tag{13}$$

  and NINT represents the nearest integer.

3.1.4 Block VENT

- `xvent`
  This parameter represents the X coordinate of the vent. Usually it is the East UTM coordinate of the vent. This parameter is not modified by PARFIT.

- `yvent`
  This parameter represents the Y coordinate of the vent. Usually it is the North UTM coordinate of the vent. This parameter is not modified by PARFIT.

- `zvent`
  This parameter represents the elevation of the vent above sea level. The generated column lies above the vent, between `zvent` and $\texttt{hcol}_i$ (see (12). This parameter is not modified by PARFIT.

3.1.5 Block FLAGS

- `modew`
  This parameter selects the χ^2 weighting factors w_i (see (1)):

  Flag: `modew=0` Constant weighting factor ($w_i = 1$).

  Flag: `modew=1` Proportional weighting factor ($w_i = 1/Y_{obs}^2$).

  Flag: `modew=2` Statistical weighting factor ($w_i = 1/Y_{obs}$).

- `iflch`
  This flag selects whether the maxima of the sub-deposits generated by each grain size class must lie in the convex hull (0=NO, 1=YES).

- `ifenl`
  This flags allows the enlargement of the convex hull by the amount specified by parameter `belthull` (0=NO,1=YES). It has effect if `iflch=1`.

- `belthull`
  This parameter specifies how much enlarge the convex hull, in meters. It has effect if both `iflch=1` and `ifenl=1`.

- `iflwgt`
  In case some ground sections do not have associated a particle grain size distribution, this flag allows the use of the grain size distrubution form the nearest point where it is available (0=NO, 1=YES).

- `vmodel`
  This flag selects the settling velocity model:

  Flag: `vmodel=1` Model of Arastoopour et al. (1982).

  Flag: `vmodel=2` Model of Ganser (1993).

  Flag: `vmodel=3` Model of Wilson and Huang (1979).

  Flag: `vmodel=4` Model of Dellino et al. (2005).

  Flag: `vmodel=5` Model of Pfeiffer et al. (2005).

  Flag: `vmodel=6` Model of Dioguardi et al. (2017).

- `smodel`
  This flag selects the Suzuki model:

  Flag: `smodel=1` Integrated Suzuki model.

  Flag: `smodel=2` Classical Suzuki model (not integrated).

- `ifvofz`
  This flag selects whether the settling velocity is allowed to vary with the altitude:

  Flag: `ifvofz=0` The settling velocity is evaluated at sea level and is assumed constant with height.

  Flag: `ifvofz=1` The settling velocity is allowed to vary with the altitude, assuming that the variations of the density and viscosity of the atmosphere follow the International Standard Atmosphere (Smithsonian, 1951).

- `ifchi`
  This flag specifies whether the list of evaluated Ξ^2 is printed in file `chi2.out` (0=NO, 1=YES).

- `ifgsp`
  This file selects the method for handling the bulk grain size distribution in the column:

  `ifgsp=0` - The whole grain size distribution in the column is read from file `column_spectrum.inp`.

  `ifgsp=1` - The grain size distribution in the column is estimated from best fitting the grain size distributions in the deposit sections, defined in file `ground_spectra.inp`.

3.1.6 Block FILES

This block is optional. It is needed only if the following file names are apecified.

- `ground_thickness`
  This parameter specifies the name of the file that contains the ground thickness. This parameter defaults to 'ground_thickness.inp' and can be omitted. If specified the file name must be enclosed between apices (see Table 1).

- `ground_spectra`
  This parameter specifies the name of the file that contains the ground spectra. This parameter defaults to 'ground_spectra.inp' and can be omitted. If specified the file name must be enclosed between apices (see Table 1).

- `column_spectrum`
  This parameter specifies the name of the file that contains the column spectrum. This parameter defaults to 'column_spectrum.inp' and can be omitted. If specified the file name must be enclosed between apices (see Table 1).

- `input_wind_file`
  This parameter specifies the name of the file that contains the input wind profile. This parameter defaults to 'wind.dat' and can be omitted. If specified the file name must be enclosed between apices (see Table 1).

3.1.7 Block AGGREGATION

This block is optional and can be used for searching the density of the aggregates.

- `iagg`
  This is the one-based index of the aggregate class in 'column_spectrum.inp' or 'ground_spectra.inp'. Its density is replaced, for each grid-search test, by the values from `rhoaggmin` to `rhoaggmax` (kg/m3), inclusive. `iagg=0`, the default, disables this additional inversion and keeps all densities read from the spectrum file. The selected density is reported as `rho-agg` in the output.

- `rhoaggmin`
  Minimum density of the aggregates.

- `rhoaggmax`
  Maximum density of the aggregates.

- `rhoaggstep`
  Step in the aggregates density search

3.2 The input file `ground_thickness.inp`

This file defines the deposit sections:

- Each record corresponds to a different ground section, with the following fields: label of the section, X and Y UTM coordinates of the section, thickness of the deposit (metres), density of the deposit.

A sample of file `ground_thickness.inp` is reported in Table 2.

3.3 The input file `column_spectrum.inp`

This file is used if the bulk grain size distribution of the eruption column is known (flag `ifgsp=0`). This is equivalent to the bulk grain size distribution of the deposit.

- The first record defines the number of particles classes (variable `ntypes`).
- The following `ntypes` records refer to each particle class. Each record has four fields: diameter of the particle (metres), density of the particle (kg/m^3), particle shape factor (adimensional, for spheres = 1), quantity of the particles (weight %).

A sample of file `column_spectrum.inp` is reported in Table 3.

3.4 The input file `ground_spectra.inp`

This file is used if the grain size distribution of the particles is specified in the deposit sections (flag `ifgsp=1`).

- The first record defines the number of particles types (variable `ntypes`).
- The following `ntypes` records refer to each particle type. Each record has three fields: diameter of the particle (metres), density of the particle (kg/m^3), particle shape factor (adimensional, for spheres = 1).
- Number of ground sections where the the particle type distribution is specified (variable `nsect`).
- A number of block equal to `nsect` follows. Each block has the following structure:
  - Label of the section (corresponding to the same label defined in file `ground_thickness.inp`).
  - List of `ntypes` records, each containing the percentage in mass of the corresponding particle type in the section. These are specified in the same order as specified above.

A sample of file `ground_spectra.inp` is reported in Table 4.

3.5 The optional input file `wind.dat`

The format of this file is the same as that used by HAZMAP.

- Number of Z-layers (`NZ`).
- A list of `NZ` records, each specifying the height of the Z-layer above sea level (in metres).
- A list of `NZ` records, each corresponding to a different Z-layer. Each record has 6 fields: year, month, day, number of Z-layer, Vx, Vy. Where Vx and Vy are the components of the wind in the Z-layer toward X (East) and Y (North)

A sample of file `wind.dat` is shown in Table 5. The example is for wind profiles with 40 layers, but you may use and arbitrary number of layers. The first record contains the number of layers (`nz`). The next `nz` records containing the quotes of the layers. Then, follow an arbitrary number of blocks of `nz` records for each wind profile. In Table 5 is reported just one wind profile, but more profiles could be needed for a complete statistics on the wind field.

4 Output files

4.1 The output file `parfit.out`

File `parfit.out` contains the results of PARFIT, that is the parameters that minimize the discrepance between the simulated deposit and the field observation (minimum χ^2).
A sample of file `parfit.out` is reported in Table 6.

4.2 The output file `chi2.out`

File `chi2.out` is generated when flag `ifchi=1` in the input file `parfit.inp`. Thi file contains the complete list of χ^2 scanned by PARFIT during the search of its minimum. This file has a number of records equal to the total combinations of parameters generated by PARFIT. Each record has the following 9 fields: Suzuki parameter `A`, Suzuki parameter λ, column height, wind intensity, wind direction, diffusion coefficient, `beta`, χ^2, number of particles types whose deposit has its baricenter inside the convex hull (variable `nctypes`). If flag `iflch=0` (ignore the convex hull), then `nctypes=ntypes`.

4.3 The output file `parfit.wnd`

File `parfit.wnd` contains the best wind found after minimizing the χ^2. It has the same structure of the input file `wind.dat` (see Sec. 3.5). With flag `rwindfile=0`, the date of the wind is set to day=0, month=0, year=0. If the input wind file is used (flag `rwindfile=1`), then `parfit.wnd` contains the best wind selected among those contained in file `wind.dat`.

4.4 The output file `parfit.cmp`

5 How to obtain and install PARFIT

Source files of PARFIT are available both as `tarball` and `git` archive. The `tarball` contains the source code, the manual in `pdf` and the installation scripts. The `git` archive contains the source code, the manual in `pdf` and `LaTeX` and the input files for manually generating the installation scripts, as descriped below.

5.1 Installing from the tarball

The `tarball` containing the source files and installation scripts is available at:

`http://datasim.ov.ingv.it/models/parfit.html`

On a Unix/Linux/MacOS system, uncompress and untar file `parfit-2.4.1.tar.gz` with the command:

```
tar xzvf parfit-2.4.1.tar.gz
```

This will generate `root` directory `parfit-2.4.1` containing the source files of PARFIT, the manual and the installation scripts. Enter the directory `parfit-2.4.1` and follow the instructions described in Section 5.2.

5.2 Configuration and installation

Once in the `root` directory of PARFIT, issue the commands `configure`, and `make install`.
After the command `make install`, the generated executable file `parfit` will be installed in the directory `$HOME/bin` (the directory bin under the home directory will be automatically created if needed). It is important that the directory `$HOME/bin` is in the PATH of your shell. After compilation you may optionally issue the command `make clean` to remove unneeded files.
The input files `parfit.inp`, `ground_thickness.inp`, `ground_spectra.inp` and the optional file `wind.dat`, contained in the directory `example` can be modified to be adapted to the user.

5.3 Installing from git

A copy of the git archive of PARFIT can be obtaind with the command:

```
git clone https://gitlab.com/gmacedonio/parfit.git
```

This will generate `root` directory `parfit` containing the `git` archive of PARFIT.
The first time you enter the directory `parfit`, issue the command:

```
autoreconf -i
```

For this command you need the autotools installed on your PC (both `autoconf` and `automake` packages).
For the installation of the program `parfit`, follow the same procedure as described ib Section 5.2.
A copy of the `pdf` manual of PARFIT is contained in the directory `doc`, together with the LaTeX input files.
Once in the directory `doc`, the manual can be re-generated with the command: `make` (eventually, preceded by: '`make veryclean`)'

5.4 Floating Point precision

PARFIT is written in FORTRAN-90 uses real(8) (double precision) arithmetics.

6 NOTE

PARFIT uses the following public domain routines:

- To define the properties of the U.S. Standard Atmosphere 1977, PARFIT uses subroutine atmosphere written by Ralph Carmichael, Public Domain Aeronautical Software, 2009 (freely available at `http:///www.pdas.com`).
- To define the convex hull of the sampled ground points, PARFIT uses algorithm 523 by W.F. Eddy, ACM TOMS 3 (1977) 411-412, available at URL `http://www.netlib.org` (TOMS, algorithm 523). Here, algorithm 523 was translated in F90 and is contained into subroutines `convex.f90` and `split.f90`.

Acknowledgments

This work was partially supported by the Italian Department of Civil Protection, INGV-DPC Agreement 2007-2009, Project V5 - “SPeeD”.

Table 1: Sample of file `parfit.inp`

```
!
! EXAMPLE OF FILE parfit.inp
!
&WIND                    ! WIND BLOCK
rwindfile = 1            ! Read file wind.dat [0=NO, 1=YES]
htropo = 11000.          ! Height of the tropopause (m)
wndmin = 40.             ! Min wind intensity (m/s)
wndmax = 45.             ! Max wind intensity (m/s)
wndstep=  5.             ! Step of the wind intensity (m/s)
dirmin = 24.             ! Min wind direction (degrees)
dirmax = 26.             ! Max wind direction (degrees)
dirstep=  2.             ! Step of wind direction (degrees)
/
!
&TURBULENCE              ! TURBULENCE BLOCK
cdmin  = 4000.           ! Horizontal diffusion coefficient
cdmax  = 4000.
cdstep =  500.
/
!
&COLUMN                  ! COLUMN BLOCK
hcolmin  = 20000.        ! Min column height
hcolmax  = 20000.        ! Max column height
hcolstep = 500.          ! Column height step
hlayer   = 500.          ! Distance between z-layers
suz1min  = 4.            ! Suzuki coefficient N.1 (A)
suz1max  = 4.
suz1step = 0.5
suz2min  = 1.            ! Suzuki coefficient N.2 (Lambda)
suz2max  = 1.
suz2step = 0.5
/
!
&VENT                  ! VENT BLOCK
xvent = 451737.        ! Coordinates of the vent
yvent = 4519302.
zvent = 0.             ! Elevation of the vent (a.s.l.)
/
!
&FLAGS                 ! FLAGS BLOCK
modew  = 0             ! Chi2 weighting mode [0-2]
smodel = 1             ! Suzuki model (1=integrated, 2=classical)
iflch  = 1             ! Check if gauss maxima are in convex hull [0=NO,1=YES]
ifenl  = 0             ! Enlarge the convex hull [0=NO,1=YES]
belthull= 1000.        ! How much enlarge the convex hull (meters)
iflwgt = 1             ! Use nearest points for spectra
vmodel = 1             ! Vsettl model 1=Arast.;2=Gans;3=W&H;4=Dellino;5=Dioguardi
ifvofz = 1             ! Flag: Vsettl. is a function of Z (0=NO, 1=YES, 2=fvcorr)
ifchi  = 0             ! Write file chi2.out (0=NO, 1=YES)
ifgsp  = 1             ! 0=use column_spectrum.inp; 1=use ground_spectra.inp
/
!
&AGGREGATION           ! OPTIONAL: fit the effective aggregate density
iagg       = 10        ! Aggregate class index (0 disables density fitting)
rhoaggmin  = 100.      ! Minimum effective density (kg/m3)
rhoaggmax  = 600.      ! Maximum effective density (kg/m3)
rhoaggstep = 100.      ! Density step (kg/m3)
/
!
```

Table 2: Sample of file `ground_thickness.inp`

```
A01   455906. 4525476.  0.199  1000.
A02   461855. 4521650.  0.652  1000.
A03   459513. 4521538.  0.764  1000.
A04   459015. 4516330.  0.085  1000.
A05   457470. 4516554.  0.115  1000.
A06   469247. 4531112.  0.194  1000.
A07   465646. 4526071.  0.508  1000.
A08   471913. 4524904.  0.317  1000.
A09   460309. 4521504.  0.739  1000.
A10   461577. 4522298.  0.737  1000.
A11   480443. 4528885.  0.186  1000.
A12   475851. 4526648.  0.253  1000.
A13   478215. 4526671.  0.194  1000.
A14   464973. 4532304.  0.066  1000.
```

Table 3: Sample of file `column_spectrum.inp`

```
10                                  # NTYPES (number of particle types listed below)
32.0000e-3    450.0   0.83   1.8 # Diameter, density, shape, percentage
16.0000e-3    450.0   0.83   1.7
8.00000e-3    450.0   0.83   2.2
4.00000e-3    600.0   0.83   2.6
2.00000e-3    800.0   0.83   2.6
1.00000e-3    900.0   0.83   2.5
0.50000e-3   1100.0   0.83   3.1
0.25000e-3   1300.0   0.83   6.4
0.12500e-3   1500.0   0.83  13.9
0.06250e-3   1700.0   0.83  10.7
0.03125e-3   1900.0   0.83   5.3
0.20000e-3    500.0   1.00  47.2
```

Table 4: Sample of file `ground_spectra.inp`

```
10 #  Parametri per il modello di Ganser
 0.8000E-02  770.0 0.85  #  1 Diameter(m), density, shape (juveniles)
 0.4000E-02  790.0 0.85  #  2 Diameter(m), density, shape (juveniles)
 0.2000E-02 1080.0 0.85  #  3 Diameter(m), density, shape (juveniles)
 0.1000E-02 1320.0 0.85  #  4 Diameter(m), density, shape (juveniles)
 0.5000E-03 1630.0 0.85  #  5 Diameter(m), density, shape (juveniles)
 0.2500E-03 1780.0 0.83  #  6 Diameter(m), density, shape (juveniles)
 0.1250E-03 2100.0 0.81  #  7 Diameter(m), density, shape (juveniles)
 0.6250E-04 2460.0 0.80  #  8 Diameter(m), density, shape (juveniles)
 0.3125E-04 2460.0 0.80  #  9 Diameter(m), density, shape (juveniles)
 0.2000E-03  400.0 1.00  # 10 Diameter(m), density, shape (aggregates)
3                    # NSECT (Number of sections)
A02                  # LABEL Section 1
 6.14                # Percentages
 7.12
 3.79
 2.42
 5.12
 7.02
12.54
14.62
19.78
21.46
A13                  # LABEL Section 2
13.61
14.77
 8.44
 5.81
47.67
 9.53
 0.12
 0.02
 0.02
 0.03
A14                  # LABEL Section 3
21.32
18.38
 8.13
 4.46
10.36
19.69
15.51
 1.91
 0.15
 0.08
```

Table 5: Sample of file `wind.dat`

```
 40
  500.
 1000.
 1500.
 2000.
 2500.
 3000.
 3500.
 4000.
 4500.
 5000.
 5500.
 6000.
[ ... 26 records deleted ]
19500.
20000.
1986  8 21  1   1.661   0.740
1986  8 21  2   3.322   1.479
1986  8 21  3   4.983   2.219
1986  8 21  4   6.644   2.958
1986  8 21  5   8.305   3.698
1986  8 21  6   9.966   4.437
1986  8 21  7  11.627   5.177
1986  8 21  8  13.288   5.916
1986  8 21  9  14.949   6.656
1986  8 21 10  16.610   7.395
1986  8 21 11  18.271   8.135
1986  8 21 12  19.932   8.874
[ ... 26 records deleted ]
1986  8 21 39  27.406  12.202
1986  8 21 40  27.406  12.202
[ ... optional arbitrary number of blocks of 40 records]
```

Table 6: Sample of file `parfit.out`

```
Parfit version: 2.2.2
Using wind file: wind.dat
Number of ground sections:   14
Using particles spectra from file: ground_spectra.inp
Number of sections with spectrum:            3
 Section: A02    Sum:  1.00010
 Section: A13    Sum:  1.00020
 Section: A14    Sum:  0.99990
Check for maxima inside convex hull: YES
List of vertices of the convex hull
A14   464973.0 4532304.0
A01   455906.0 4525476.0
A05   457470.0 4516554.0
A04   459015.0 4516330.0
A13   478215.0 4526671.0
A11   480443.0 4528885.0
Number of tests:            1
FLAG:    B
CHI2:     0.99421
TOTMASS:  0.56648E+09
VOL(DRE): 0.21788E-03 (km3)
HCOL:    20000.0
CSUZ1:    4.000
CSUZ2:    1.000
CDIFF:    4000.0
P-TYPE   wt%   Vset (at sea level)
  9   52.563      6.7938
 10   47.437      11.013
SUM: 100.000
WARNING: Min. chi2 lies on parameters borders
 BDRY: CSUZ1   4.00000000000000
 BDRY: CSUZ2   1.00000000000000
 BDRY: COLUMN HEIGHT   20000.0000000000
 BDRY: DIFF. COEFF.   4000.00000000000
     PT Vset(sealev)       X_mass      Y_mass    Distance
OUT  1    0.64772E-03 291694979.4 134189328.5 318805492.5
OUT  2    0.25877E-02  73322233.5  36963382.6  79766707.5
OUT  3    0.10324E-01  18684857.3  12637221.6  19958639.5
OUT  4    0.40473E-01   5071057.4   6575958.9   5056476.8
OUT  5    0.14985       1670156.4   5061778.1   1333726.4
OUT  6    0.56111        757398.7   4655391.6    334588.4
OUT  7     1.3913        566784.6   4570524.6    125935.4
OUT  8     3.6853        492991.9   4537669.9     45159.2
IN   9     6.7938        473674.9   4529069.4     24014.0
IN  10     11.013        464440.6   4524958.0     13905.8
```

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