USER'S MANUAL

ATLAS-1.0

Atmospheric Lagrangian Dispersion Model

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Contents

1 Introduction

ATLAS-1.0 (ATmospheric LAgrangian diSpersion) is an atmospheric dispersion and sedimentation Lagrangian model tailored to volcanic tephra/ash. The model solves the Advection-Diffusion-Sedimentation equation across multiple scales (from regional to global) and can be driven off-line by different numerical weather prediction models in combination. ATLAS can be used in forward mode to forecast ash dispersal from a volcano (or from extended sources) or in backward mode to integrate trajectories backwards in time and constrain unknown source term characteristics. Multiple source terms can be defined, with different granulometric characteristics on a single model execution. The model is written in FORTRAN 90 for Unix-Linux OS.

2 Atmospheric dispersion model

In this section is presented a brief description of ATLAS main equations.

2.1 Physical model

ATLAS uses a zero acceleration scheme to integrate particle trajectories in time. Given the position of a particle $\mathbf{x}(t)$ at time t, the position at time $t + \Delta t$ is computed as:

$$\mathbf{x}(t + \Delta t) = \mathbf{x}(t) + (\mathbf{v_a}(\mathbf{x}, t) + \mathbf{v_d}(\mathbf{x}, t) + \mathbf{v_s}(\mathbf{x}, t))\,\Delta t \tag{1}$$

where the velocity vector $\mathbf{v}(\mathbf{x}, t)$ is composed of the wind advection (passive transport), atmospheric diffusion, and particle sedimentation.

2.2 Diffusion

The diffusive velocity is obtained from the Langevin equation:

$$dv = adt + bdW, \tag{2}$$

where a is the deterministic term of the lagrangian velocity (equation 3), b is the aleatory term related to turbulent statistical properties, and dW is the differential Wiener process with zero mean and variance dt which follows a Markov process. The term bdW describes the diffusion process (equation 4). In the planetary boundary layer (PBL), the Hanna scheme [Hanna, 1982] is utilized, parameterizing the wind fluctuations, depending on the atmospheric conditions (stable, neutral, and unstable):

$$a = -\frac{v}{T_{i,L}}, \tag{3}$$

$$b = \sqrt{\frac{2\sigma_v^2}{T_{i,L}}}, \tag{4}$$

where, σ_v^2 is the variance of the wind speed, and $T_{i,L}$ is the Lagrangian integral time scale. In the free troposphere, a constant horizontal diffusivity of $50m^2/s$ is considered along x and y components whereas the z component is set to 0 [Stohl et al., 2005]. In contrast, in the stratosphere, a vertical diffusivity of $0.1m^2/s$ is fixed and no horizontal diffusivity is assumed [Legras et al., 2003].

2.3 Sedimentation

Assuming that particles settle down at its terminal velocity, the sedimentation velocity is given by:

$$|\mathbf{v_s}| = v_s = \sqrt{\frac{4g(\rho_p - \rho_a)d}{3C_d\rho_a}} \tag{5}$$

where ρ_a and ρ_p are the air and particle densities respectively, d is the particle equivalent diameter, and C_d is the drag coefficient that depends on the Reynolds number $Re = dv_s/\nu_a$, being ν_a the air kinematic viscosity (*i.e.* $\nu_a = \mu_a/\rho_a$ where μ_a is the air dynamic viscosity). ATLAS admits as empirical parameterisations for the terminal velocity different models that the user need to choose:

1. Arastoopour model [Arastoopour et al., 1982]. Model valid for spherical particles in which the drag coefficient is calculated as:

$$C_d = \begin{cases} \frac{24}{Re}(1 + 0.15Re^{0.687}) & Re \leq 988.947 \\ 0.44 & Re > 988.947 \end{cases} \tag{6}$$

2. Ganser model [Ganser, 1993]. In this model the drag coefficient is obtained as:

$$C_d = \frac{24}{ReK_1}\left[1 + 0.1118(ReK_1K_2)^{0.6567}\right] + \frac{0.4305K_2}{1 + \frac{3305}{ReK_1K_2}} \tag{7}$$

where $K_1 = 3/\left[(d_n/d) + 2\psi^{-0.5}\right]$ and $K_2 = 10^{1.8148(-Log\psi)^{0.5743}}$ are two form factors, d_n is the average between the particle minimum and maximum axes sizes, d is the diameter of the equivalent volume sphere, and

ψ is the particle sphericity, calculated as the Wadell sphericity [Aschenbrenner, 1956, Wadell, 1933] based on the three particle dimensions and its volume:

$$\psi_w = 12.8 \frac{(P^2Q)^{1/3}}{1 + P(1+Q) + 6\sqrt{1 + P^2(1+Q^2)}} \tag{8}$$

with $P = S/I, Q = I/L$, where L is the largest dimension, I is the largest perpendicular to L, and S is the direction perpendicular to L and I.

3. Wilson model [Walker et al., 1971, Wilson and Huang, 1979]. This model uses the interpolation suggested by Pfeiffer et al. [2005] for the drag coefficient:

$$C_d = \begin{cases} \frac{24}{Re}\varphi^{-0.828} + 2\sqrt{1-\varphi} & Re \leq 10^2 \\ 1 - \frac{1 - C_d|_{Re=10^2}}{900}(10^3 - Re) & 10^2 \leq Re \leq 10^3 \\ 1 & Re \geq 10^3 \end{cases} \tag{9}$$

where $\varphi = (b + c)/2a$ is a particle form factor, ($a \geq b \geq c$ are the particle semi-axes).

4. Dellino model [Dellino et al., 2005]. This model gives the sedimentation velocity (for particle diameters constrained to those used in the Dellino et al. [2005] experiment) without need of iteratively solving eq. (5):

$$v_s = 1.2605 \frac{\nu_a}{d} (Ar\xi^{1.6})^{0.5206} \tag{10}$$

where $Ar = gd^3(\rho_p - \rho_a)\rho_a/\mu_q^2$ is the Arquimedes number, g the gravity acceleration, and ξ a particle form factor.

2.4 Meteorological data

ATLAS requires of time-dependent meteorological data (wind velocity, air temperature and density, friction velocity, atmospheric boundary layer height, and Monin-Obukhov length) and the terrain topography. This first version of the model admits data from the Weather Research and Forecast (WRF) mesoscale model and/or from the Global Forecast System (GFS) produced by the National Centers for Environmental Prediction (NCEP). ATLAS transforms values of meteorological fields from pressure levels to the background mesh terrain-following coordinates. It is desirable that the user indicate as the spatial resolution of this background (interpolation) mesh, a similar to that of the driving meteorological model. ATLAS background mesh resolutions finer than that of the meteorological model increase the computational cost without improving model accuracy whereas coarser background mesh resolutions cause a loss of information. In the case of more than one meteorological input being used, ATLAS stores at each grid point the value of the meteorological model with higher resolution and performs a smooth blending at the interfaces.

2.5 Source term

ATLAS-1.0 admits different types of source term:

1. Eruption source, used to simulate tephra/ash dispersal from an eruption column or co-ignimbritic cloud. This type of source is automatically generated by the model for different parameterizations of the vertical distribution of mass released along the column and of the mass eruption rate depending on column height and wind conditions (see below).

2. Diffused source, intended for simulation of ash resuspension events or to assimilate ash cloud observations from satellites. Diffused source terms are read from an external file containing the position (coordinates) and the characteristics of the particles. For now, only is possible read a diffused source in term of a partiles set dispersed to simulate backwards in time.

3. Restart source, used to continue a previous simulation from a set of particles that remained airborne at the end of a previous run.

Different sources and/or different types of sources can coexist. In the case of eruption source(s), particles are released at each time integration step and distributed in vertical above the vent using one of the following options, that the user needs to specify,

- POINT_SOURCE, all the particles are released at a heigh equal to that of the eruption column:

$$M(z) = \begin{cases} M_0 & z = H \\ 0 & z < H \end{cases} \tag{11}$$

  where $M(z)$ is the is the mass vertical distribution function, M_0 is the (total) eruption mass flow rate (in kg/s), H is the maximum column height (above the terrain), and z is the vertical coordinate ($0 \leq z \leq H$).

- TOP_HAT, particles are equally distributed and released within a height slab determined by the maximum column height H and thickness W:

$$M(z) = \begin{cases} \frac{M_0}{W} & (H-W) \leq z \leq H \\ 0 & z < (H-W) \end{cases} \tag{12}$$

- LINEAR, particles are linearly distributed between the vent and the column height:

$$M(z) = \frac{2M_o}{H}\left(\frac{z}{H}\right) \tag{13}$$

- SUZUKI, particles are vertically distributed according to [Pfeiffer et al., 2005, Suzuki, 1983]:

$$M(z) = M_0 \left[\left(1 - \frac{z}{H}\right) e^{A\left(\frac{z}{H}-1\right)}\right]^{\lambda} \tag{14}$$

  where A and λ are dimensionless parameters. The parameter A controls the vertical location of the maximum whereas the parameter λ controls the distribution of mass around the maximum.

Regardless of the type of vertical distribution adopted, different parameterisations exist in ATLAS to compute the total mass flow rate M_o from the (time-dependent) column height and, eventually, from atmospheric conditions. The user needs to specify one of this if it is the case,

- MASTIN [Mastin et al., 2009]. Simple and classical relationship between column height and mass eruption rate based on best-fit of ground deposit data:

$$H = 2\left(\frac{M_o}{\rho}\right)^{0.241} \tag{15}$$

  where ρ is the deposit density (Dense Rock Equivalent).

- DEGRUYTER [Degruyter and Bonadonna, 2012]. In this parameterisation the mass flow rate M_o is estimated from column height H, wind velocity v and air potential temperature θ_a profiles, and source enthalpy as:

$$M = \pi \frac{\rho_{a0}}{g'} \left(\frac{2^{\frac{5}{2}} \alpha^2 \overline{N}^3}{z_1^4} H^4 + \frac{\beta^2 \overline{N}^2 \overline{v}^3}{6} H^3 \right) \tag{16}$$

  where β ($\approx$ 0.5) and α ($\approx$ 0.1) are wind entrainment coefficents, $z_1 = 2.8$ is a non-dimensional height, $\overline{v}$ and $\overline{N}$ are the average buoyancy frequency (Brunt-Väisälä frequency) and wind velocity across the plume height:

$$\overline{N}^2 = \frac{1}{H}\int_0^H N^2(z)dz = \frac{1}{H}\int_0^H \frac{g^2}{c_{a0}\theta_{a0}}\left(1 + \frac{c_{a0}}{g}\frac{d\theta_a(z)}{dz}\right)dz \qquad (17)$$

$$\overline{v} = \frac{1}{H}\int_0^H v(z)dz \qquad (18)$$

g is the gravity acceleration, ρ_{a0}, c_{a0}, and θ_{a0} are reference (vent) air density, heat capacity, and potential temperature respectively, and g' is defined as:

$$g' = g\frac{c_0\theta_0 - c_{a0}\theta_{a0}}{c_{a0}\theta_{a0}}, \qquad (19)$$

- WOODHOUSE [Woodhouse et al., 2013]. In this parameterisation the mass flow rate M_o is estimated from column height H as

$$H = 0.318M^{0.253}\frac{1 + 1.373W_s}{1 + 4.266W_s + 0.3527W_s^2} \qquad (20)$$

with

$$W_s = \frac{1.44V_1}{NH_1} \qquad (21)$$

where $V_1 = V(H_1)$ is the wind velocity at a reference height H_1 (*e.g.* the tropopause), and N is the Brunt-Väisälä frequency.

2.6 Particle aggregation

ATLAS considers aggregation phenomena in a simplistic way and assumes that the aggregation processes occur only in the eruption column. Aggregation is taken into account by modifying the TGSD file a priori, *i.e.* adding an additional aggregate particle class and depleting the mass fraction of lower-size particle classes. Two options are available when aggregation modeling is activated:

1. PERCENTAGE [Sulpizio et al., 2012]. This option extracts a user-defined percentage from all particle classes having a particle diameter lower than that of the aggregate.

2. CORNELL [Cornell et al., 1983, Costa et al., 2012]. This option, based on observations from the Y-5 layer of the Campaginan Ignimbrite, adds to the aggregated class a 50% of particles with a diameter between $3 < \Phi < 4$, a 75% of particles with a diameter between $4 < \Phi < 5$, and 90% of particles with $\Phi > 5$.

3 Running ATLAS

ATLAS-1.0 is provided with a scheme of directories and files, see scheme in figure 1. In this scheme, the user can create folders and files for each study case. The main folder is ATLAS and whitin it, are folders divided according their functionality.

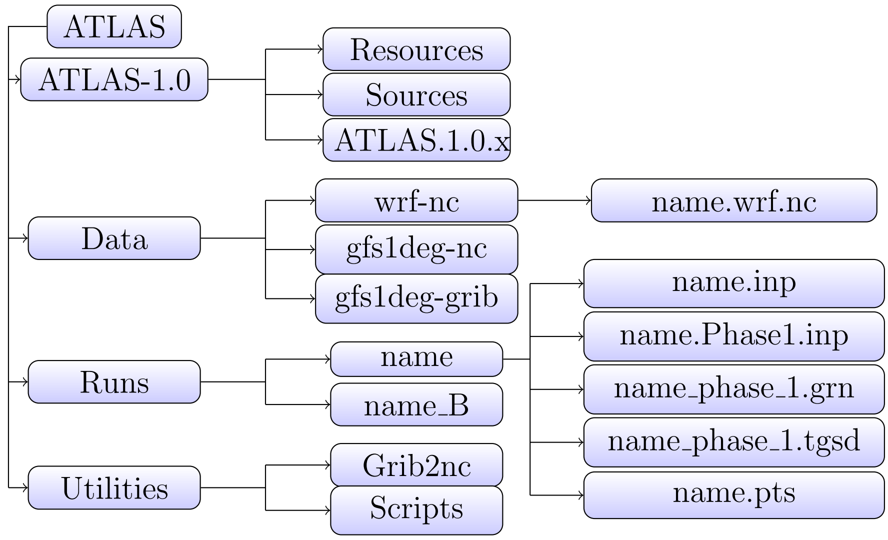

Figure 1: Directories and files scheme of ATLAS 1.0

To run ATLAS-1.0 is necesary to complete data in the required input files. ATLAS-1.0 can be used in forward mode with specific input files indicating all the simulation information required to obtain finally the tephra trajectories, concentrations, and load accumulation. The ATLAS-1.0 flow for forward mode is presenting in figure 2. In backward case, there is a dispersed set of particles which are necesary to model backaward in time. Then, the input files are different. The ATLAS-1.0 flow for backward runs is presented in figure 3. When ATLAS-1.0 is executed, all the output files are saved on the same directory. There are examples input files in the Sources directory.

4 Input files

4.1 The input file name.inp

The main input file include the principal information needed to simulate. This file is divided in blocks.

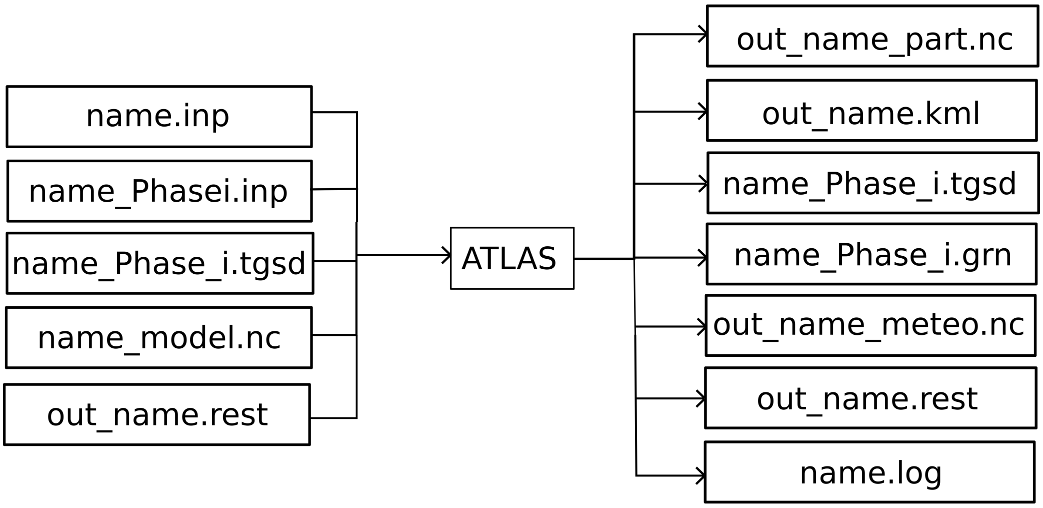

Figure 2: ATLAS-1.0 flow for forward mode

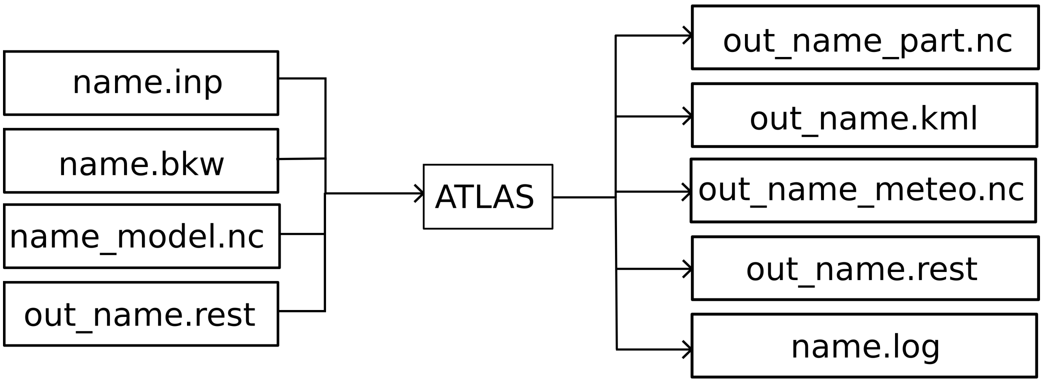

Figure 3: ATLAS-1.0 flow for backward mode

The first block, with simulation time information must be completed, line per line, as follows,

- YEAR, a four-digit integer value referring the year in which the simulation begins.
- MONTH, a two-digit integer value with the month in which the simulation begins.
- DAY, a two-digit integer value with the day in which the simulation begins.
- SIMULATION_START, an integer value, in hours from 00:00 UTC of the DAY/MONTH/YEAR

- SIMULATION_END, an integer value, in hours from 00:00 UTC of the DAY/MONTH/YEAR. In this part, is important to note that if SIMULATION_END is less tha SIMULATION_START, a backwards integration is performed.
- TIME_STEP : Simulation Increment Time in seconds.
- RESTART, the options are YES or NO. If the present simulations consist of the continuation of a previous one, then is important to start this with the particle suspended and deposited information to continue the transport and accumulate the deposit.

It follows a computational domain block. The computational domain is the grid where the information is restored, but it is not an Eulerian grid. In this block, the user must complete the following information,

- LATMAX, maximium latitude in degrees. A value between -90 and 90.
- LATMIN, minimium latitude in degrees. A value between -90 and 90.
- LONMAX, maximium longitude in degrees. A value between -180 and 180.
- LONMIN, minimium longitude in degrees. A value between -180 and 180.
- ZTOP, maximium modeling height. A value in meters, which should be higher than the volcanic column height in case to simulate an eruption.
- VERTICAL_RESOLUTION, value in meters. Set the vertical spacing to store the interpolated meteorological information to calculate the particle transport. It is recomended to set it as the meteorological file resolution.
- LONGITUDE_RESOLUTION, value in degree. Set the xhorizontal spacing to store the interpolated meteorological information to calculate the particle transport. It is recomended to set it as the meteorological file resolution.
- LATITUDE_RESOLUTION, value in degree. Set the yhorizontal spacing to store the interpolated meteorological information to calculate the particle transport. It is recomended to set it as the meteorological file resolution.

The next block is referred to the output grid characteristics,

- OUTPUT_LATMAX, maximium limits for output file. Value in degree.
- OUTPUT_LATMIN, minimium limits for output file. Value in degree.
- OUTPUT_LONMAX, maximium limits for output file. Value in degree.
- OUTPUT_LONMIN, minimium limits for output file. Value in degree.
- OUTPUT_FREQUENCY, time interval to extract information, in hours.
- VERTICAL_LAYERS, distance between vertical layers (only one number) or vertical leyers enumerated, in meters.
- LONGITUDE_RESOLUTION, value in degrees.
- LATITUDE_RESOLUTION, value in degrees.
- OUTPUT_CLASSES, options are YES/NO. If yes, then the output file include output variables per particle classes.
- OUTPUT_PHASES, options are YES/NO, If yes, then the output file include output variables per particle phases.
- OUTPUT_TRACK_POINTS, options are YES/NO. If yes, an extra output file is generated per track point with load information in that location.

The next block contain physics information. For now, only the vertical velocity model in consideration for the simulation.

- TERMINAL_VELOCITY_MODEL, options are 0,1,2,3,4. Where 0 correspond to the Stokes model, 1 is the Arastoopour model, 2 the Ganser, 3 is the model of Wilson & Huang, and 4 is Dellino model. Select the model to parameterize the terminal velocity.

A meteorological data information block is added. Diferent meteo models can be considered simultaneously. Each meteo model is defined by the tags METEO_MODEL_DEFINITION and END_METEO_MODEL_DEFINITON Between this, is necessary to complete the information:

- Activate, options are yes/no. If yes, this meteorological file is used in the simulations.
- MODEL_TYPE, options are WRF/GFS/DEBUG.
- FILE, indicate the file_path.

- POSTPROCESS, options are yes/no. If yes, an output file is generated, showing the meteorological variables used in the simulation.

Finally, Different sources (phases) can be considered simultaneously. Each phase is defined by the tags PHASE_DEFINITION and END_PHASE_DEFINITION. Between these, is necessary to complete the information,

- ACTIVATE, options are yes/no. If yes, this pahse is used in the simulation.
- INCLUDE, indicate the file_path coresponding to the secondary input file. Where is detailed the phase charaacteristics.

4.2 The input file name_Phasei.inp

This input file contain all the information about the source term. If the user want to run with n source terms, then is necessary to complete the file *name_Phasei.inp* for i from 1 to n, i.e. so many files as source term to model.This file contain the next information,

- NUMBER_PARTICLES, an integer denoting the total number of particles in this phase. (can be slightly modified by ATLAS to make it as a multiple of the number of time steps.
- PHASE_NAME, character denoting the name of this phase.
- PHASE_TYPE, options are ERUPTION/SATELITE/RESUSPENSION. For now, is only available the type ERUPTION.
- INITIAL_TIME, start time in hours since simulation start indicated in the *name.inp* file. This time is referred to the eruption start. Multiple values are possible if there are changed in the column height.
- END_TIME, in hours since simulation start indicated in the *name.inp* file. Only one value.
- SOURCE_TYPE, options are point/linear/top-hat/suzuki. Only for eruption type.
- COLUMN_HEIGHT, value in meters, above Vent.
- MASS_FLOW_RATE, options are a value in KG/s or ESTIMATE-MASTIN/ESTIMATE-DEGRUYTER/ESTIMATE-WOODHOUSE.
- A_SUZUKI, value only for Suzuki source type.

- L_SUZUKI, value. only for Suzuki source type.
- D_TOP_HAT, value in meters. only for Top-hat source type.
- VOLCANO_NAME, Volcano name or unknown.
- SOURCE_LONGITUDE, value in degree.
- SOURCE_LATITUDE, value in degree.
- SOURCE_ELEVATION, value in meters.
- PHASE_GRANULOMETRY, Path_where_the_granulometry_file_is/file_name.ext or "NONE". If in the previous line a directory and graulometry file is provided, the next 7 lines are not necessary, else (if "NONE" option was used) ATLAS generate a TGSD distribution according the next lines:
- DISTRIBUTION, o GAUSSIAN/BIGAUSSIAN.
- NUMBER_OF_BINS, an integer indicating the number of groups to divide the TGSD.
- FI_MEAN, mean value of grain diameter. A second value is used if DISTRIBUTION=BIGAUSSIAN.
- FI_DISP standard deviation value of grain diameter. A second value is used if DISTRIBUTION=BIGAUSSIAN.
- FI_RANGE, minimium and maximium values of grain diameter.
- DENSITY_RANGE, minimium and maximium values of particles density (a linear interpolation is used to asign density values to all bins).
- SPHERICITY_RANGE, minimium and maximium values for sphericity (a linear interpolation is used to asign density values to all bins).
- AGGREGATION_MODEL, options are NONE/CORNELL/PERCENTAGE,a ccording the model to consider aggregation.
- AGGREGATE_SIZE : value in microns.
- AGGREGATE_DENSITY, density for the aggregate class.
- PERCENTAGE_(%), value in percentage, only for Percentage Model.

4.3 The input file name_Phase_i.tgsd

This input file can be ceated by ATLAS, providing all the necessary information. But, if there is available a total grain size distribution, is better provide a file with the specific information. The format of this file is shown in table 1,

Table 1: *name_Phase_i.tgsd* file format

nc			
diam(1)	rho(1)	sphe(1)	fc(1)
...			
diam(nc)	rho(nc)	sphe(nc)	fc(nc)

4.4 The input file name.pts

This is an optional input file in ATAS. Only added if the user wants to obtain information (thickness and load deposited) in specific points. This is a file in ASCII format and contain the points geographical information (longitude and laitude). The file format is presented in table 2, in which, *n* is the toal number of points, *name* is the user defined name for each point, *lon* and *lat* are the point longitude and latitude. A point characteristics are defined per row.

Table 2: *name.pts* file format

name(1)	lon(1)	lat(1)
...		
name(n)	lon(n)	lat(n)

4.5 The input file name_model.nc

ATLAS needs meteoroogical data (topography and time dependant data as the wind field, temperature, humidity, etc.) to simulate the particle transport. ATLAS read only data in netCD format. WRF data comes in that format, then the user only needs to indicate in the input file *name.inp* the meteorological file directory and name. Instead, GFS data comes in grib format. Then, first is necessary transform it to netCDF format. For this, a utility program is added. The GRIB2NC is the utility program provided with

FALL3D model. Once the GFS file is transformed in netCDF format, the user only needs to indicate the file path and name in the input file *name.inp*.

4.6 The input file out_name.rest

This file is generated as output file in each simulation. If the user want to continue the simulaton, then need to copy this output file obtained in the previous (in time) simulation to the new directory and rename it as *out_name.rest*, where *name* is the new name.

4.7 The input file name.bkw

If the user want to simulate in backward mode (backwards in time) is necessary this file with the particle dispersed information (deposited or in air). This is asn ASCII file, the format is showed in table 3, where *np* is the total number of particles descripted below, *i* is the particles numbering, *rho* is the particle density, *diam* is the ddiameter, *mass* the particle mass, and *sphe* the sphericity. In continuity the geogprahical information mut be added, *lon*, *lat*, and *z* are the longitude, latitude and height respectively. Each row contain the information for one particle.

Table 3: *name.bkw* file format

	TOTAL_PARTICLES = np						
1	rho(1)	diam(1)	mass(1)	sphe(1)	lon(1)	lat(1)	z(1)
...	...	...	...	...	...	...	...
i	rho(i)	diam(i)	mass(i)	sphe(i)	lon(i)	lat(i)	z(i)
...	...	...	...	...	...	...	...
np	rho(np)	diam(np)	mass(np)	sphe(np)	lon(np)	lat(np)	z(np)

5 Output files

When the simulaton is end or during the execution, ATLAS produce the next output files.

5.1 out_name_part.nc

This file is written in netCDF format. There are several free rograms to open netCDF files and generate images and animations. This file contain information about

- Topography
- Ash load on ground. Also, if the user indicated, the ash load per particle classes and/or particle phases.
- Ash concentrations in different specific heights indicated by the user in the input file. Also, if the user indicated so, the ash concentrations at the same height levels per particle class or per particle phase.
- Column mass.

5.2 out_name.kml

This file is written in *kml* format. Could be open in Google Earth to look the particles trajectories.

5.3 name.tps.point_name.res

This optional output file is written in ASCII format. Contain information about load (kg/m^2) and thickness (cm) deposited on the point *point_name* for each time step.

5.4 name_Phase_i.tgsd

This is an output file only if the user does not included it as input. ATLAS generate this file automatically with a Gaussian or bi-Gaussian distribution.

5.5 name_Phase_i.grn

This file is in ASCII format and it is generated by ATLAS since the *name_Pase_i.tgsd* file, where i is the phase number in consideration. Is necessary to have one per phase. This file take into account the aggregation class. The file format is shown in table 4, where nc is the total number of particle classes (this nc could be different than the used in the *name_Pase_i.tgsd* file when aggregation is considered), *rho* is the class density, *sphe* the sphericity, *fc* is the mass fraction asociated to each class and their values are between 0 and 1, and satisfy that $\sum fc = 1$. Finally, *class* is the label which describes the class as a particle class or as the aggregate class.

Table 4: Formato del archivo *name_Phase_i.grn*

nc					
diam(1)	rho(1)	sphe(1)	fc(1)	class(1)	(e.g. class-01)
...					
diam(nc)	rho(nc)	sphe(nc)	fc(nc)	class(nc)	(e.g. aggregate)

5.6 out_name_meteo.nc

This optional output file is written in netCDF format. Contain the following information,

- The computational domain used for the simulation, Lonngitude, latitude aand height information.
- Times in which the variables are readed.
- Time an spatial resolution.
- Longitude, latitude and heights of the grid where the information is stored.
- Topography.
- Meteorological model used in each grid point (usefule when more than one meteorological file is used).
- Meteorological variables used to simulate.

5.7 out_name.rest

This file is written in ASCII format and can be used to obtain succesive execution of ATLAS activating the *restart* option in the input file. This file is created at the end of the simulation. If the user wnat to obtain a simulation that continues the present, need to copy this file to the new directory and rename it, and configure the input file indicating "YES" in the RESTART option inside the SIMULATION_TIME block.

5.8 name.log

This file cntain a detailed onformation about the simulation, error and warning messages. This file is written in ASCII format ad give information about the program version, times (initial, final) for the simulation, names and directories for input and output files, meteorological range used, parameters used, information about concentration during the simulation, among others.

6 Program Installation and execution

ATLLAS-1.0 is written in FORTRAN 90, tested in UNIX/Linux. To compile the code, available only in serial version is required:

- FORTRAN 90 compiler.
- Library netCDF installed. This is available from https://www.unidata.ucar.edu/software/ne
- To use the GRIB2NC utility program to decode meteorological GRIB files from GFS is necessary to have wgrib or wgrib2 available from http://www.cpc.ncep.noaa.gov/products/wesley/wgrib.html. For more information about GRIB2NC, see FALL3D references [**??**].

To install ATLAS-1.0 is necessary to edit the Makefile according the specific netCDF directory and fortran compiler. Then, in a terminal move to the ATLAS source directory ($cd ATLAS/ATLAS-1.0/Sources/), and executed the command: $make The executable file is installed in the directory ATLAS-1.0.
To run ATLAS go to the corresponding folder *name* inside the Run directory, complete all the inputs file and make a dinamic link to the executable file and run $ ./ATLAS-1.0.exe name
All the output files will be created and saved in the same *name* directory.

7 Example

A run example is proposed with a GFS meteorological file, which is in format netCDF on the directory Data/gfs1deg-nc, called ejemplo.gfs1deg.nc. In the directory Runs/ejemplo are tree input files: *ejemplo.inp*, *ejemplo.Phase1.inp*, and *ejemplo.Phase2.inp*. Note that this is not a real example, only fulfills the rol of testing ATLAS-1.0.
To run this example the user need to modify the input file *ejemplo.inp* with the correct directory where the files (see meteorological block and phases block, and change the word "COMPLETE..." by the correct directory) are in the pc, and then go to the directory Runs/ejemplo, copy or make a dynamic link to Atlas.1.0.exe in this directory and execute:
./Atlas.1.0 ejemplo

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