User manual: python-FALL3D

A procedure for modelling volcanic ash hazards

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Introduction

PURPOSE

Fall3D models the dispersal of volcanic ash during explosive eruptions in order to determine how ash is concentrated in the atmosphere and where it is deposited at ground level. The purpose of this manual is to introduce a new user with no modelling background to Fall3D. This will be achieved through step-by-step instructions for installing and running simulations of volcanic ash fallout, both for validation (historical eruptions) and predictive (ongoing or future) purposes. Fall3D has been incorporated into a larger framework called python-FALL3D for the purpose of simplifying the volcanic ash modelling procedure for volcanologists with no programming or computational modelling background.

SCOPE

This manual will provide instructions for installing and running python-FALL3D in a Unix/Linux environment. It will incorporate step-by step instructions for creating volcanological, meteorological and topographic input files, running an eruptive scenario and viewing the results.

AUDIENCE

This resource is intended for geoscientists and natural hazard modellers with a volcanological background but no computer programming background.

Background

The distribution and thickness of volcanic ash deposited during mildly to highly explosive volcanic eruptions has important life safety, livelihood, economic and political implications for densely populated areas that are affected. A number of computational modelling tools have been developed in recent decades for forecasting the transport and deposition of volcanic ash. Fall3D is one of these tools and was developed by Osservatorio Vesuviano (http://datasim.ov.ingv.it/Fall3d.html). Fall3D is able to model the distribution and thickness of volcanic ash on the ground and in the atmosphere during explosive volcanic eruptions. It has the ability to volcanic ash dispersion in a 3-dimensional wind field that experiences changing wind speed, direction and air temperature over time. Fall3D also considers the interaction between topography and the 3D wind field and the impact this may have on dispersal of ash at ground level.

The hazard models produce isopach maps. An isopach is a contour line connecting points of equal volcanic ash thicknesses (or ash load or ash concentration etc). Therefore each map may contain isopachs of ash thicknesses that vary in appearance according to the volcanological and wind conditions of the eruption that the user is modelling.

UNIX setup instructions

Python-FALL3D is designed to run in a UNIX/Linux environment such as Ubuntu Linux. Although directories and output files can be viewed and manipulated through the windows manager the user is still required to run the model from a UNIX command line using a terminal window. The user is therefore required to know a number of basic UNIX commands. These are usually combinations of typed characters. There are four main commands to remember for navigating through a UNIX environment:

- **cd** *<directory name>* - **CHANGE DIRECTORY**
  (Open this directory)

- **cd ..** *(type a space after cd)* - **GO UP ONE DIRECTORY**
  (Close this directory and open the parent directory)

- **cd ../..** *(type a space after cd)* - **GO UP TWO DIRECTORIES**
  (Keep adding "**/..**" to go up more than two directories)

- **ls -l** *(type a space after ls)* - **LIST**
  (Show me a list of what is inside this directory)

- **pwd** - **PRINT WORKING DIRECTORY**
  (Show me where I am located)

- **cp** *<filename> <directory>* - **COPY THIS FILE** and move it to **THIS DIRECTORY**

- **cp *.**<*extension*> *<directory>* - **COPY ALL FILES WITH THIS EXTENSION** and move them to **THIS DIRECTORY**

- **mkdir** – **MAKE DIRECTORY**
  (Make a new directory (folder) at this location – this is followed by a space and the name of the new directory)

Other commands that the user may require to use python-FALL3D include:

- **svn co** - **CHECKOUT**
  (Refers to 'checking out' a repository, scripts etc)

- **python** – **RUN PYTHON SCRIPT**
  (This is then followed by a space and the name of the python script that the user would like to run)

- **ln –s** – **LINK**
  (Allows you to create a shortcut to a specified directory from the current directory)

Initial Installation

The steps to install PYTHON-FALL3D and Fall3d are outlined below. Specific pathnames apply to alamba users however the instructions also apply more generally to other Linux systems.

STEP 1 – INSTALLING PYTHON-FALL3D

Instructions for installing python-FALL3D onto your PC for use in a linux/UNIX environment are detailed below. Green text highlights the UNIX commands that are used. Blue text indicates the path to be taken and red text indicates other variables such as file names, websites and usernames. You will only need to follow this step once for initial setup purposes.

The “<” and “>” symbols indicate that the user must insert information in this space and not include the symbols themselves (see example below).

Eg.

mkdir /model_area/sandpit/<username>
mkdir /model_area/sandpit/bearad

1. Open a new terminal (double click on the display icon on the desktop)

2. To create a work area directory (known as a sandpit) in AIFDR’s modelling area type:

mkdir /model_area/sandpit/<username> (<username> e.g. bearad)

3. To create a shortcut to your sandpit type:

ln -s /model_area/sandpit/<username> ~/sandpit

4. To change directory into your sandpit type:

cd ~/sandpit

5. To get python-FALL3D from the AIFDR repository type:

svn co --username <userame> http://www.aifdr.org/svn/aim/branches/fall3d_v6 aim

6. To change to the python-FALL3D source code directory type:

cd ~/sandpit/aim/source/aim

7. To install python-Fall3D type:

python install_fall3d.py

8. When prompted with 'update .bashrc file (Y or N) type:

Y

Optional: The location of the output data is controlled by the environment variable called TEPHRADATA. It is specified in the system file named .bashrc in your home directory. If you want the output data to be stored elsewhere you can edit the .bashrc file using the following procedure:

a. Open a new terminal

b. Type **emacs .bashrc**

c. The **.bashrc** file will open

d. Scroll down to the line

export TEPHRADATA=/model_area/tephra

(Customise the pathway for output data - the default will be always be **/model_area/tephra** for alamba users)

f. Close the terminal window

STEP 2 – TESTING PYTHON-FALL3D

We have developed a script called **test_all.py** which will test if the installation was successful.

1. Open a new terminal

2. Change to the directory:

cd ~/sandpit/aim/testing

3. To run the test script type:

python test_all.py

STEP 3 – VALIDATION SCENARIOS

Fall3D has been validated against a number of historical eruptions in order to ensure the modelled outputs accurately reproduce observed ash thickness and loads. Two validation scenarios are included with the installation of python-FALL3D; the 1840 eruption of Gunung Guntur, Indonesia and the 1994 eruption of Tavurvur Volcano, Papua New Guinea. It is important that users run each validation and compare the generated outputs for stored model outputs included in reference data at part of the python-FALL3D installation. This serves to verify that the installation of python-FALL3D works as intended.

Validation Scenario #1 – 1840 Gunung Guntur, Indonesia

This scenario was developed in July 2010 to validate Fall3D against observed ash thicknesses from the Guntur 1840 eruption by Nugraha Kartadinata, Anjar Heriwaseso, Adele Bear-Crozier, Ole Nielsen, Antonio Costa, Arnau Folch and Kristy Vanputten at a workshop held at the Australia-Indonesia Facility for Disaster Reduction in Jakarta.

Modelled outputs were compared against observed volcanic ash thickness measured in the field at Gunung Guntur by N. Kartadinata and published internally at PVMBG.

1. Open a new terminal

2. Change to the directory:

cd ~/sandpit/aim/validation/guntur

3. To run the Guntur 1840 scenario type:

python guntur1840.py

4. To view model results change into the directory:

cd /model_area/tephra/scenarios/guntur1840/<username>

(or navigate to your customised **TEPHRADATA** area)

5. Compare model output with stored model output for the Guntur 1840 eruption located in the directory below and shown in Figure 1;

cd ~/sandpit/aim/validation/guntur/reference_data/model_ouputs

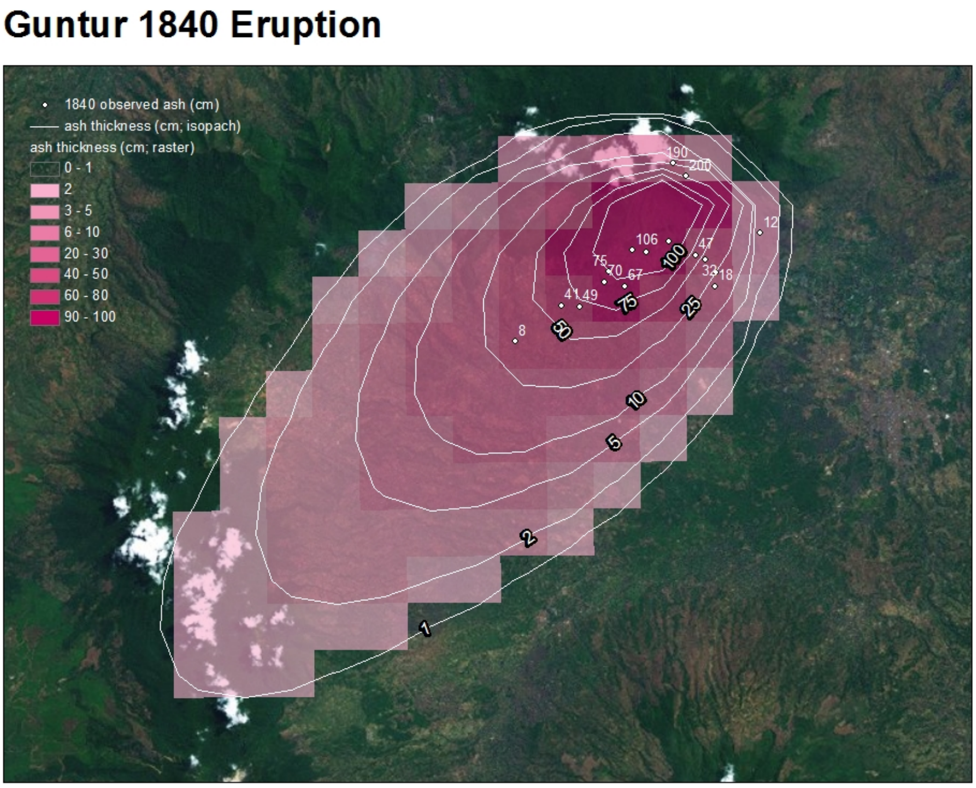

Figure 1 – Stored model output for the 1840 eruption of Gunung Guntur showing good agreement with observed ash thickness collected at 15 localities: White points = measured observed ash thicknesses (cm) from G.Guntur (N. Kartadinata); White lines = ash thickness (cm) isopach map generated by Fall3D; Pink = ash distribution (thickness in cm) generated by Fall3D used to construct isopach map.

Validation Scenario #2 – 1994 Tavurvur Volcano, Papua New Guinea

This scenario was developed in August 2010 to validate Fall3D against observed ash thicknesses from the 1994 eruption of Tavurvur Volcano, East New Britain, Papua New Guinea by James Goodwin and Adele Bear-Crozier at Geoscience Australia, Canberra. Modelled outputs were compared against ash thickness observations collected within the nearby township of Rabaul (destroyed during the eruption) published by Blong and McKee (1995) and Blong (2003).

1. Open a new terminal

2. Change to the directory:

cd ~/sandpit/aim/validation/tavurvur

3. To run the Tavurvur 1994 scenario type:

python tavurvur.py

4. To view model results change into the directory:

cd /model_area/tephra/scenarios/tavurvur/<username>

5. Compare model output with stored model output for the Guntur 1840 eruption located in the directory below and shown in Figure 2;

cd ~/sandpit/aim/validation/tavurvur/reference_data/model_ouputs

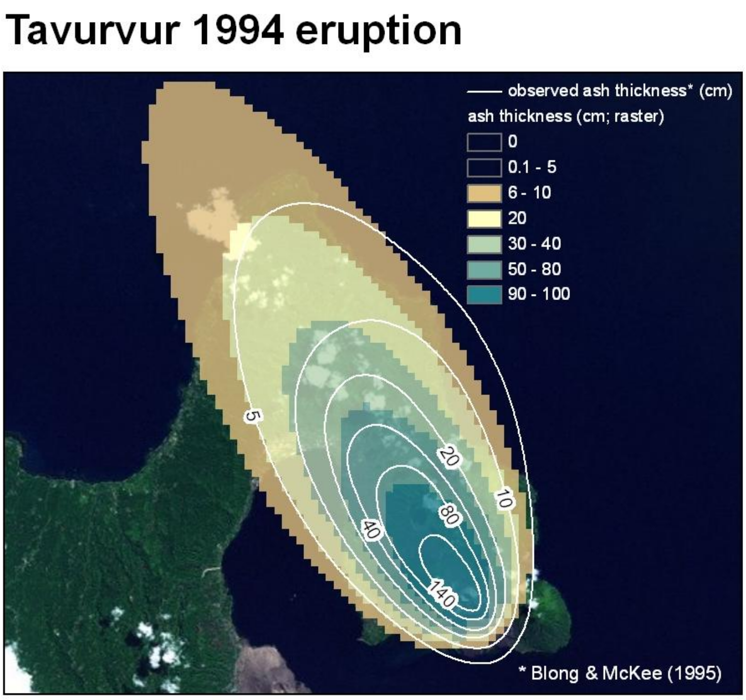

Figure 2 – Stored model output for the 1994 eruption of Tavurvur Volcano showing good agreement with observed ash thickness isopach map produced by Blong and McKee (1995; white lines).

STEP 4 – MODELLING AREA

Python-FALL3D has now been successfully downloaded and installed. The validation scripts have been run to test the success or failure of that installation process. Each new user must now set up a modelling area. This is the directory where the user will edit all scripts and run the model.

The example below is for an alamba user to create a modelling area within their sandpit however Python-FALL3D is designed to run from any location. Non-alamba users are encouraged to follow this procedure at a location of their choosing.

1. Open a new terminal

2. Change into the directory:

cd /model/sandpits/<username>

3. To create a modelling area type:

mkdir volcanic_ash_modelling

A directory named **volcanic_ash_modelling** has now been created in the sandpit and is ready to be populated with python scripts from the templates directory.

STEP 5 – TEMPLATES

The templates directory contains example scripts which the user can copy into their modelling area edit and run as needed. There are three template scripts.

To copy these scripts to the modelling area:

1. Open a new terminal

2. Change into the directory:

cd ~/sandpit/aim/templates

3. To view a list of the five template scripts type:

ls -l

The following list will appear:

volcano.py
extract_windprofiles.py
create_hazard_maps.py

4. To copy these scripts into a new modelling area type:

cp *.py *<volcanic ash modelling directory>*

eg. alamba users

cp *.py ~/sandpit/volcanic_ash_modelling

All files with the extension '.py' will be copied into the modelling area specified by the user. These files can then be edited and run as needed.

5. To confirm that the modelling area has been populated with the five template scripts navigate to the location of the modelling area:

eg. alamba users

cd /model_area/sandpits/<username>/volcanic_ash_modelling

6. Type:

ls –l

A list of template scripts will appear ready for use.

Model Run Setup

The three template scripts are used individually and in combination depending on the type of scenario being modelled. Table 1 outlines three modelling procedures available to users and the scripts used for each (including the order in which they are run).

Procedure	Description	Python scripts
Scenario-based	A procedure used to model a fixed volcanological scenario with a single wind profile. Most single scenario based modelling will be undertaken using this methodology.	**extract_windprofiles.py** **volcano.py**
Hazard Map	A procedure used to model a fixed volcanological scenario and multiple wind profiles. Useful for probabilistic wind modelling but is computationally time consuming and should be run in parallel.	**extract_windprofiles.py** **volcano.py** **create_hazard_maps.py**
Forecasting	A procedure used to model a fixed volcanological scenario with forecast wind data automatically downloaded from a website.	**volcano.py**

STEP 6 - TERRAIN MODEL

Python-FALL3D requires a terrain model and accompanying projection file. Terrain model files are required to be in ESRI ASCII format. Alamba users have access to a database of USGS (Shuttle Radar Topography Mission) digital elevation models (DEM) of various spatial resolutions for every volcano in Indonesia as well as their accompanying projection files. The location of the DEM can be input directly into the modelling script under the section "Terrain model". Other users:

1. Use the template in Appendix 1 to format a suitable DEM and accompanying projection file.

STEP 7 - PREPARATION OF METEROLOGICAL DATA

The scenario-based and hazard map modelling procedures require NCEP1-reanalysis wind data. The user must download data for the required time period and the required area (a location close the eruptive vent) NOAA website. This data captures the 4-times daily wind conditions for a user specified domain and is particularly useful for recent eruptions (more than 4 days ago) and probabilistic wind (i.e. wind behaviour post 1948). The forecast modelling procedure uses predicted wind conditions generated by the Australian Bureau of Meteorology (BoM) model ACCESS-T. A 24 hour forecast is downloaded automatically from the web when specified in the script **volcano.py** and no prior downloading is required.

SCENARIO OR HAZARD MAP

1. Download NCEP data for the time and location needed using the instructions in Appendix 2.

Modelling Procedure

STEP 8 – SCENARIO-BASED

This procedure details how to run a fixed volcanological scenario using a single merged wind field extracted from NCEP1-renalysis meteorological data – a deterministic approach.

1. Open a new terminal

2. Navigate to your volcanic ash modelling directory

/model_area/sandpits/<username>/volcanic_ash_modelling

3. To view the contents of this directory type:

ls -l

The following list will appear:

extract_windprofiles.py
volcano.py
create_hazard_maps.py (not needed)

The user will have downloaded NCEP data using the procedure outlined in Appendix 2. If this step has not been taken return to Step 6 – Preparation of Meteorological Data and follow the instructions. The user must now edit and run **extract_windprofiles.py** which will extract the necessary wind data from the NCEP files and merge them into a single file suitable for input into Fall3D.

3. Open **extract_windprofiles.py** using a text editor by typing:

emacs extract_windprofiles.py (other users open using preferred editor)

4. Enter the location of the vent for the volcano being modelling (decimal degrees; the wind data will be extracted closest to this point).

5. Enter the UTM zone (Refer to the projection file)

6. Enter the hemisphere (S or N; refer to the projection file)

5. Enter a start time for the meteorological data extraction (Options: 0, 6, 12 or 18)

6. Enter an end time for meteorological data extraction (Options: 0, 6, 12 or 18)

7. In the field 'Location of NCEP files' you need to specify the location (directory) where the NCEP data you downloaded in Step 6 using instructions from Appendix 2 is stored (an example is provided in the template script). There should be 4 files within this directory; TMP.nc, HGT.nc, UGRD.nc and VGRD.nc

8. You need to specify a name for the directory where your extracted wind profiles will be located. This directory will be created in the same location that you run the script (an example is provided in the template script – no pathway necessary)

There are two wind field types:

A '**merged**' profile contains several time blocks (6 hour intervals) all merged together to form a single profile with a start date and an end date. Time intervals are given in blocks of 21600 seconds (6 hours). i.e. the first block will be for the time interval 0 to 21600 and then the second time block will be for 21600 to 43200 and so on. You select the '**merged**' profile option when running a single scenario. This is the option you will use most often.

The '**multiple**' profile option is for when you want to run a single volcanological scenario with multiple wind fields in conjunction with the create_hazard_map.py script (see Alternative Modelling Procedure). This option will generate one profile every six hours but will **NOT** merge them and will not indicate a time interval. They will be stored collectively in a directory and used by python-FALL3D to run multiple scenarios if the user specifies this in the scenarioname.py script (see Alternative Modelling Procedure).

9. To generate a '**merged**' profile needed for **scenario based modelling** type:

wind_field_type = 'merged'

10. Save and close.

11. To run type:

python extract_windprofiles.py

A new directory of wind profiles will be generated in the modelling area.

12. Open **volcano.py** using a text editor by typing:

emacs volcano.py (other users open using preferred editor)

Use the volcanological input worksheet in Appendix 4 to plan your ash fall scenario. The worksheet represents a hard copy version of the python script and it is particularly important for establishing the type of meteorological data you are using and where it is located (Options are a **single merged file (scenario based)**, directory of multiple profiles (hazard mapping) or a website (forecasting)).

14. Use the worksheet to input the variables into **volcano.py**

Note: Remember to enter the **file name and location** of the **merged** vertical wind profile generated by extract_windprofiles.py – this will inform python-FALL3D that a scenario run is in progress).

15. Save as **<volcano>.py** and close (e.g **merapi.py**)

16. To run type:

python <volcano>.py (eg. **python merapi.py)**

VIEWING SCENARI-BASED RESULTS:

Scenario results for ash load and ash thickness are generated in grid, ascii, shapefile and Google Earth format. Individual scenarios are time stamped, the output files are organised by time interval (usually 1 hour) and stored in:

~/model_area/tephra/scenarios/<volcano>/<username>

(or navigate to your customised **TEPHRADATA** area)

STEP 9 – HAZARD MAPPING

This procedure details how to run a fixed volcanological scenario using multiple wind fields extracted from NCEP1-renalysis meteorological data **-** a probabilistic approach. The results of each scenario are merged into a single hazard map showing probability (%) of exceeding a user defined volcanic ash load threshold (kg/m2). Multiple hazard maps can be generated for multiple ash threshold values.

The user will have downloaded NCEP data using the procedure outlined in Appendix 2. If this step has not been taken return to Step 6 – Preparation of Meteorological Data and follow the instructions.

1. Follow Step 7 – Scenario-Based Modelling for numbered points 3 to 8.

2. To generate '**multiple'** profiles needed for hazard mapping type:

wind_field_type = 'multiple'

3. Save and close.

4. To run type:

python extract_windprofiles.py

A new directory containing multiple extracted wind profiles (with the extension .profile) will be generated in the modelling area (these profiles differ from merged profiles as they have no time intervals associated with them).

5. Open **volcano.py** using a text editor by typing:

emacs volcano.py (other users open using preferred editor)

Use the volcanological input worksheet in Appendix 4 to plan your ash fall scenario. The worksheet represents a hard copy version of the python script and it is particularly important for establishing the type of meteorological data you are using and where it is located (Options are a single merged file (scenario based), **directory of multiple profiles (hazard mapping)** or a website (forecasting)).

6. Use the worksheet to input the variables into **volcano.py**

Note: Remember to enter the **directory name and location** of the **multiple** vertical wind profile generated by extract_windprofiles.py – this will inform python-FALL3D that a scenario run is in progress).

7. Save as **<volcano>.py** and close (e.g **merapi.py**)

8. To run in parallel type the following substituting with the available nodes (see example below):

mpirun -x FALL3DHOME -x PYTHONPATH -hostfile /etc/mpihosts -host node<#>,node<#> **python volcano.py**

eg.

mpirun -x FALL3DHOME -x PYTHONPATH -hostfile /etc/mpihosts –host node1,node2,node3,node4 **python merapi.py**

9. Note the location of scenario results as this a required input below in (17).

10. Open **create_hazard_map.py** using a text editor by typing:

11. Enter the location of the vent for the volcano being modelling (decimal degrees; the wind data will be extracted closest to this point).

12. Enter the UTM zone (Refer to the projection file)

13. Enter the hemisphere (S or N; refer to the projection file)

14. Enter a list of ash thresholds values (kg/m^2; one hazard map generate for each ash load threshold)

15. Optional: enter a list of flight level (concentration) values (kg/m^3; one hazard map generate for each ash load threshold)

16. Optional: edit '**PLOAD_contours**' to include user-defined intervals (in %). The default **'True'** will automatically determine contour intervals based on the spread of data.

17. You need to specify the name and location of the directory where the scenario outputs that were generated in (9) as these are used to generate the hazard map(s).

18. To run type:

python create_hazard_maps.py

VIEWING HAZARD MAP RESULTS:

Hazard maps are generated in grid, ascii, shapefile and Google Earth format. They are organised by ash load interval (as pload1, pload2 etc) and are stored in the directory specified in (17).

~/model_area/tephra/hazard_mapping/<volcano>/<username>

(or navigate to your customised **TEPHRADATA** area)

STEP 10 – FORECASTING

This procedure details how to run a fixed volcanological scenario using forecasted wind data produced by the BoM model ACCESS-T. The modelling procedure is similar to scenario-based modelling however the meteorological input is a website ACCESS-T generates new 72 hour forecasts for wind speed, direction and air temperature every 12 hours. Python-FALL3D downloads a 24 hour forecast (most reliable), converts it into a Fall3D compatible format and runs the fallout model for a projected 24 hour period **-** a forecasting approach

1. Open **volcano.py** using a text editor by typing:

emacs volcano.py

Use the volcanological input worksheet in Appendix 4 to plan your ash fall scenario. The worksheet represents a hard copy version of the python script and it is particularly important for establishing the type of meteorological data you are using and where it is located. Options are a single merged file (scenario based), directory of multiple profiles (hazard mapping) or a **website (forecasting)**.

2. Type this link to online ACCESS-T data into the '**Meteorological_input**' section as follows:

wind_profile = 'ftp://ftp-newb.bom.gov.au/register/sample/access/netcdf/ACCESS-T/pressure/'

3. Save as **<volcano>.py** and close (e.g **merapi.py**)

4. To run type:

python <volcano>.py (eg. **python merapi.py)**

VIEWING FORECASTED RESULTS:

Forecasted results for ash load and ash thickness are generated in grid, ascii, shapefile and Google Earth format. Individual scenarios are time stamped, the output files are organised by time interval (usually 1 hour) and stored in:

~/model_area/tephra/scenarios/<volcano>

(or navigate to your customised **TEPHRADATA** area)

Appendix 1 – Template for terrain model

1. Digital Elevation Model File Format

alamba: topography_grid = ‘/model_area/tephra/dems/<volcano>/usgs_srtm_<volcano name>_<km>_<cellsize>.txt’

```
ncols         59
nrows         64
xllcorner     412432.33601038
yllcorner     9106708.627275
cellsize      1000
NODATA_value  -9999
358 347 335 325 358 376 404 442 469 488 548 575 578 664 690 779 814 850 964 951 975 1091 1164 1234 1366
1426 1562 1586 1571 1420 1370 1296 1095 986 924 836 789 751 659 615 545 517 484 432 405 393 351 352 287
```

1. Projection File Format

alamba: topography_grid = ‘/model_area/tephra/dems/<volcano>/usgs_srtm_<volcano name>_<km>_<cellsize>.txt’

```
PROJCS["WGS_1984_UTM_Zone_48S",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298
.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433]],PROJECTION["Transverse_Mercator"]
,PARAMETER["False_Easting",500000.0],PARAMETER["False_Northing",10000000.0],PARAMETER["Central_Meridian",
105.0],PARAMETER["Scale_Factor",0.9996],PARAMETER["Latitude_Of_Origin",0.0],UNIT["Meter",1.0]]
```

Appendix 2 – Downloading NCEP1 - Reanalysis Meteorological Data

1. Navigate to the website:

http://www.esrl.noaa.gov/psd/data/reanalysis

2. Select from the list of dot-points:

"The 6-hourly and daily data currently available on-line."

3. Select from the list of blue dot points:

"Pressure Level"

This will take you to the webpage for extracting NCEP Reanalysis 1 data at multiple **pressure levels** for the domain you wish to model

There are 4 variables that need to be downloaded: Air temperature, Geopotential Height, U wind and V-wind. There are three options for each variable: 4 times daily, daily and monthly mean. We are only interested in four times daily data (not daily or monthly).

4. Click on the coloured map for "Air Temperature (4 times daily)" to open a new webpage.
5. Click on the coloured map "Make a plot or subset" to select the region for download (i.e. Indonesia, Philippines, PNG etc) to open a new webpage.
6. Under "*Axis Dimensions*": enter the coordinates for the region that you would like to download NCEP data for: (e.g. Indonesia: lat begin: 20N, lat end: 10S, lon begin: 95E, lon end: 160E)
7. Under *"Other dimension values(s)"*: select 1000.00 millibar from the pressure level list. Hold down the shift button on your keyboard and **select all** the other pressure levels (right down to 10 millibar - this means you would like air temperature data for **every** pressure level)
8. Select the date you wish to download in UTC time.
9. Under *"Output options"*: select "Create a subset without making a plot"
10. Under *"Plot output options*": deselect "Color plot"
11. Select "Create Plot or Subset of Data" to open a new webpage.
12. Select "FTP copy of the file"
13. Save the file when prompted
14. Return to the webpage with the first colour map (Step 4).
15. Repeat steps 4-14 for the three remaining variables "Geopotential Height", "u-wind" and "v-wind".
16. You should have 4 files with the extension **.nc** at the conclusion of the download process
17. Rename the Air Temperature file "**TMP.nc**"
18. Rename the Geopotential Height file "**HGT.nc**"
19. Rename the u-wind file "**UGRD.nc**"
20. Rename the v-wind file "**VGRD.nc**"

You have now successfully downloaded and stored the NCEP data.

Appendix 3 – Volcanological input worksheet

 # Short eruption comment to appear in output directory.
eruption_comment = ____

#Temporal parameters

eruption_start =__________________________# Hours relative to the start of wind data
eruption_duration =_________________________# Hours
post-eruptive_settling_duration =_______________# Hours (to allow for ash settling)

 # Location
x_coordinate_of_vent = _____________________# UTM zone implied by projection
y_coordinate_of_vent =______________________# UTM zone implied by projection

 # Vertical discretisation for model domain
z_min = _________________________________
z_max = ________________________________
z_increment = ____________________________

 # Meteorological input
wind_profile = _____________________________# Path to wind data or online forecasts

eg. *scenario based: /model_area/tephra/ . . . /volano.profile* *hazard mapping: /model_area/tephra/ . . . /volcano_2010* *forecasting:* *ftp://ftp-newb.bom.gov.au/register/sample/access/netcdf/ACCESS-T/pressure/*)

 # Terrain model
topography_grid = __________________________# Path to topography file

i.e **/model_area/tephra/dems** . . . /volcano.txt

 # Granulometry
grainsize_distribution = ______________________# Possibilities are
GAUSSIAN/BIGAUSSIAN(modal/bimodal)
number_of_grainsize_classes = _______________
mean_grainsize = __________________________# phi
sorting = ________________________________
minimum_grainsize = _______________________# phi
maximum_grainsize = _______________________# phi
density_minimum = ________________________# kg/m3
density_maximum = ________________________# kg/m3
sphericity_minimum = ______________________
sphericity_maximum =______________________

# **Source**
vent_height = ________________________________# meters
source_type = ________________________________# Possibilities are **'plume', 'suzuki', 'point'**
mass_eruption_rate = __________________________# kg/s (if unknown **'estimate')**
height_above_vent = ___________________________# m
A = ____# (suzuki only)
L = ____# (suzuki only)
height_or_MFR = _____________________________# plume only
MFR_minimum = ______________________________# kg/s (plume only)
MFR_maximum =______________________________# kg/s (plume only)
exit_velocity = _______________________________# m/s (plume only)
exit_temperature = ____________________________# K (plume only)
exit_volatile_fraction = ________________________# % (plume only)

# **Fall3D**
terminal_velocity_model = ______________________# Possibilities are
ARASTOOPOR/GANSER/WILSON/DELLINO
vertical_turbulence_model = _____________________# Possibilities are CONSTANT/SIMILARITY
horizontal_turbulence_model = ___________________# Possibilities are CONSTANT/RAMS
vertical_diffusion_coefficient = __________________# m2/s
horizontal_diffusion_coefficient = ________________# m2/s
value_of_CS = ________________________________# RAMS only

# **Contouring**
thickness_contours = ___________________________# if unknown 'True'
load_contours = _______________________________# kg/m2
thickness_units = ______________________________# mm, cm, m

Appendix 4 – Range table

The range table below details the acceptable range of eruption column heights, eruption column increments, mass eruption rates and eruption durations that should be adhered to when considering a new scenario. The table is based on the volcano explosivity index (VEI).

Ranges	**VEI 2***	**VEI 3**	**VEI 4**	**VEI 5**	**VEI 6**	**VEI 7**	**VEI 8**
Eruption column height (m)	2000-5000	3000-15000	10000-25000	25000-30000	30000-50000	30000-50000	50000+
Eruption column height increments (m)#	1000	1000-10000	10000	10000	10000	10000	10000
Mass eruption rates (kg/s)	$1x10^{4}$-$1x10^{6}$	$1x10^{4}$-$1x10^{6}$	$1x10^{5}$-$1x10^{8}$	$1x10^{5}$-$1x10^{8}$	$1x10^{9}$-$1x10^{12}$	$1x10^{9}$-$1x10^{12}$	$1x10^{9}$-$1x10^{15}$
Eruption duration (hours)	1-6	1-6	1-6	6-12	>12	>12	>12

** Fall3D will not model effusive eruptions (VEI 0) or eruptions that produce eruption columns <2000m in height (VEI 1).*
 # Increments must always be the same magnitude of order as the eruption column height (i.e. 3000m (1000 increments; 40000m (10000)

Appendix 5 – Glossary of volcanological and meteorological terms used by Fall3D

Point

Mass of an eruption column is released at a single source point (Refer to Fall3d-6.2 user's manual at http://www.bsc.es/projects/earthscience/fall3d)

Suzuki

Mass of an eruption column released according to an empirically derived formula (Refer to Fall3d-6.2 user's manual)

Plume

Mass of an eruption column released according to the buoyant plume theory. (Refer to Fall3d-6.2 user's manual)

Rams/ Constant (horizontal)

Equations for solving the horizontal diffusion co-efficient of settling particles. (Refer to Fall3d-6.2 user's manual)

Similarity/ Constant (vertical)

Equations for solving the vertical diffusion co-efficient of settling particles. (Refer to Fall3d-6.2 user's manual)

ARASTOOPUR

Mathematical formula for estimating the settling velocity of particles. (Refer to Fall3d-6.2 user's manual)

GANSER

Mathematical formula for estimating the settling velocity of particles. (Refer to Fall3d-6.2 user's manual)

WILSON

Mathematical formula for estimating the settling velocity of particles. (Refer to Fall3d-6.2 user's manual)

DELLINO

Mathematical formula for estimating the settling velocity of particles. (Refer to Fall3d-6.2 user's manual)