PUFF – Volcanic Ash Dispersion Modeling
PUFF-AFWA Version 3.00
User's Guide

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1 Introduction

1.1 Purpose

This document is the user's guide for the PUFF volcanic ash dispersion modeling programs, which predict the geographical distribution of volcanic ash from an eruption versus time.

1.2 Background

PUFF is a volcanic ash dispersion prediction tool. PUFF was developed at the Geophysical Institute, University of Alaska Fairbanks and used by the Alaska Volcano Observatory (AVO) for volcano monitoring. Initially, PUFF was a research tool conceived by Dr. Hiroshi Tanaka for predicting the movement of eruption clouds. Dr. Craig Searcy conceived and developed the present version of PUFF as part of his PhD program. This version is used by the National Weather Service (NWS) and AVO to track volcanic eruption clouds.

Refinements in the Graphical User Interface (GUI) and data conversions were implemented by The Johns Hopkins University Applied Physics Laboratory (JHU/APL) in a joint project with the University of Alaska. JHU/APL is responsible for modifying the program and/or developing supporting utilities to facilitate its deployment at the Air Force Weather Agency (AFWA) site at Offutt AFB, NE. An additional responsibility is to develop a basic documentation set including this document. The system is currently in operation at the Air Force Weather Agency (AFWA).

1.3 Overview

The PUFF program models the dispersion of volcanic ash from an eruption and provides predictions of ash particle locations (latitude/longitude/altitude) versus time given eruption characteristics and wind field forecasts produced by another model. The PUFF application suite comprises five executable programs (puff, afwa2puff, puffgui, puffview, and ashdump) that provide the modeling capability; input data preprocessing; a graphical user interface (GUI) for model run specification; a GUI for viewing results; and utilities for viewing summaries of binary file contents. The application is written in C++, while the associated GUI functions are largely handled via the Tool Command Language (Tcl) scripts employing Toolkit (Tk) Motif widgets. The application suite can be hosted on Unix systems.

The PUFF model predicts the movement of ash particles ejected from a volcano versus time. The operator may select from a number of different initial conditions for the ash distribution and particle size. Particle locations are computed for each integration step (typically 5 minutes), with a snapshot of all particle locations at a given summation time (typically one or more hours) being written to an ash file.

For input, PUFF requires the name of a volcano, eruption characteristics, and forecasts of wind speeds for the time period of interest. The wind speed data must be available in gridded binary (GRIB) files. At AFWA, these required wind GRIB files are produced by a variety of models. PUFF's afwa2puff program converts the GRIB file outputs of the various wind models to U and V wind velocity versus geopotential height files. The U and V files serve as inputs for PUFF's volcanic ash tracking model. PUFF's puffview program displays a map of the area surrounding the volcano of interest overlaid with a graphical depiction of the ash distribution and overlaid with location identifier labels (pushpins). The PUFF volcanic ash tracking model outputs a series of ash files in Network Common Data (netCDF) format, describing the ash distribution over time.

The processes used in the model and an analysis of model results versus observations are given in “PUFF: A high-resolution volcanic ash tracking model,” (see reference 1).

1.4 Components

Table 1 PUFF Suite Executables identifies and provides a brief description of the roles of the PUFF application suite components.

Table 1 PUFF Suite Executables

Executable	Role
puff	Contains the volcanic ash dispersion model and is executed for each model run.
puffgui	GUI invoked by the operator and used to specify model parameters and select source wind data for use by the model; automatically invokes afwa2puff (wind data conversion), puff (model), and puffview (view results) as necessary.
puffview	GUI normally invoked automatically by puffgui following a model run. This displays a map of an area surrounding the volcano of interest overlaid with a graphical depiction of the ash distribution and overlaid with location identifier labels (pushpins).
ashdump	Utility normally invoked by puffview to extract data from the ash files produced during the model run. It can also be invoked from the command line by a knowledgeable operator to inspect ash data.
afwa2puff	Utility normally invoked by puffgui to convert wind speed data contained in gridded binary (GRIB) files into a form usable by the puff executable. Can also be invoked from the command line to automate source wind file creation.

1.5 Document Organization

Section 1 describes the scope of the PUFF application system.

Section 2 lists applicable references.

Section 3 walks through a sample PUFF run.

Section 4 provides a detailed description of the operation of “puffgui”, the GUI front end to the execution of “puff”.

Section 5 describes puff operation, including its command line operation.

Section 6 describes “puffview,” which provides a vehicle for viewing the results and for generating gifs and charts.

Section 7 describes "afwa2puff" which converts wind model data.

Section 8 describes use of the ashdump utility.

Section 9 covers maintenance methods for changing default values and windfile naming conventions.

Section 10 provides a quick reference guide to program operation.

Section 11 provides troubleshooting tips.

Section 12 provides a list of acronyms and abbreviations.

2 References

1. “PUFF: A high-resolution volcanic ash tracking model,” Journal of Volcanology and Geothermal Research 80 (1998) pp1-16, Craig Searcy, Ken Dean, and William Stringer

2. “NetCDF User’s Guide for C – An Access Interface for Self-Describing, Portable Data”, Version 3, Russ Rew, Glenn Davis, Steve Emmerson, and Harvey Davies, Unidata Program Center, June 1997 - http://www.unidata.ucar.edu/packages/netcdf/index.html

3. “The WMO Format for the Storage of Weather Product Information and the Exchange of Weather Product Messages in Gridded Binary Form as used by NCEP Central Operations,” Clifford H. Dey, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, National Centers for Environmental Prediction Office Note 388, GRIB (Edition 1), 10 March 1998

3 Sample Program Run

The following instructions assume that Puff has been installed per the installation instructions. This requires that the user's path statement include directories containing a number of executables. You can verify that your path covers the needed executables by executing the Unix "which" function for each of the following executables and ensuring that the executable is found:

a. Puff and related executables installation
```
%> which puff
```

b. GRIB reader utility installation
```
%> which wgrib-afwa
```

c. netCDF library and utility installation
```
%> which ncdump
```

d. ghostscript Postscript reader installation
```
%> which gs
```

e. ImageMagick image file conversion tool installation
```
%> which convert
```

f. Generic Mapping Tools (GMT) installation
```
%> which pscoast
```

If any of these did not return an executable filename, review the installation procedures and verify the correct setting of the path variable for your login and the location of the executables.

What follows is a single example run that involves the most common options. The complete set of options for each stage is presented in a subsequent section.

3.1 Specify Eruption Parameters

Type the following at the command line to start the GUI front-end for PUFF:

```
%> puffgui
```

A splash screen containing information about the program and its development history is displayed for a few moments while the application is initializing. Then the main puffgui window is displayed (Figure 1).

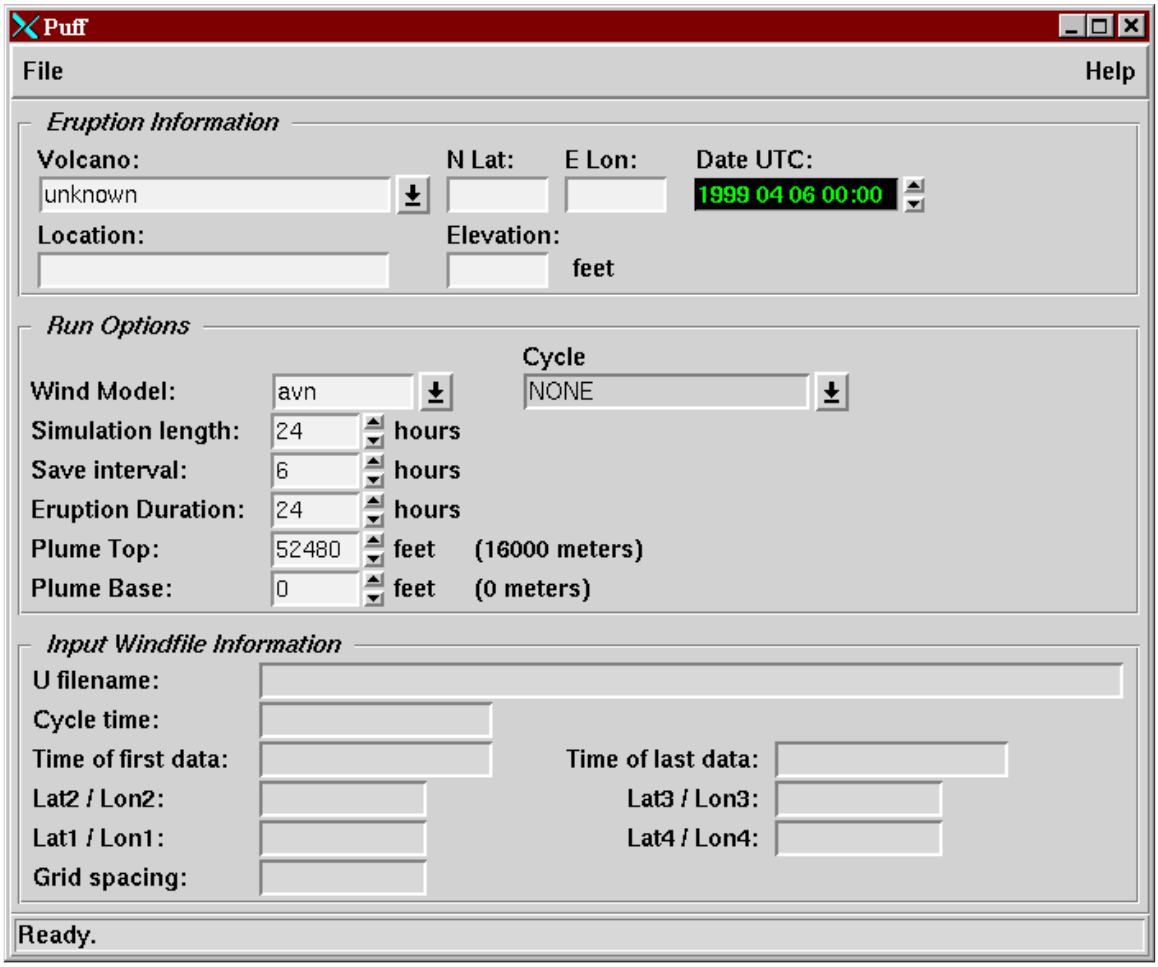

Figure 1 Main Puffgui Window

Click on the volcano combo box drop-down arrow and select the SHISHALDIN volcano from the list. After selecting the volcano, information about its location will appear in the remaining Eruption Information display widgets. Note that latitude is reported in decimal degrees North (90 to –90) and longitude in decimal degrees East (-180 < lon <= 180). A negative North latitude is equivalent to a positive South latitude.

Specify the date and time of the beginning of the eruption by adjusting the time in the Date display accordingly. The displayed date/time defaults to the current date/time. To alter the date a small amount, click on the upward or downward pointing arrows to the right of the display. By holding the button down, the date will change continuously. The amount of change will also become greater after each four-second period. This process may be somewhat slow if the date needs to be changed many days. In such a case the better approach is to specify the date as a parameter on the puffgui command line:

```
%> puffgui –eruptDate “1999 04 06 00:00”
```

NOTE: Wind data must be available for the time period bounded by the eruption date and the simulation duration.

3.2 Create Input File

Select the File|GRIB convert … menu item to bring up the windfile conversion dialog box (Figure 2). Change the minimum and desired "Forecast Hours to Convert" entries to 12 and click on the "Create PUFF files" button. This will extract a subset of the U and V windspeed data and geopotential height data from the AVN model global data GRIB files based on the location of the volcano and the specified latitude and longitude range (in whole degrees, not decimal degrees) around the volcano.

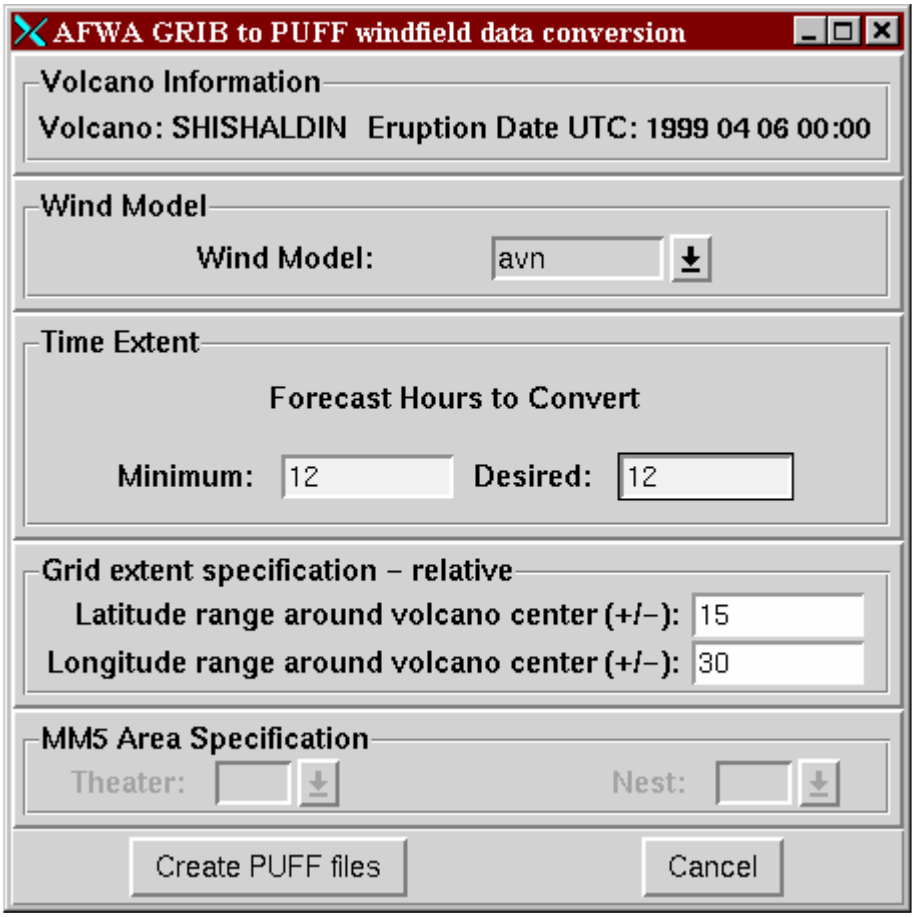

Figure 2 Windfile Conversion Dialog Box

An informational dialog box with a progress indicator will be displayed. When the PUFF input files have been created, the progress dialog and the conversion dialog disappear and control returns to the main puffgui dialog. The input wind files that were just created are automatically selected and appear in the Wind Model and Cycle entries in the "Run Parameters" section and a summary of the files' contents appear in the "Input Windfile Information" area.

NOTE: The windfield file name shown on your display may differ from the one shown in the figure. The name and path depends on the path specified for your system, the weather model used to generate the source data, and the eruption date selected.

3.3 Specify Model Run Parameters

Specify the following characteristics for this run:

Simulation length:	12 hours – This specifies the period of time over which the model predicts ash dispersion
Save interval:	2 hours – This is the granularity of the result (i.e., ash cloud locations are reported at this time step over the period defined by simulation length)
Eruption duration:	0.5 hours – The period of time during which the volcano continues to emit particles
Plume top:	50000 feet
Plume base:	9371 feet (note that this defaults to the cone elevation given in the Eruption Information area of the window)

The result should look like Figure 3.

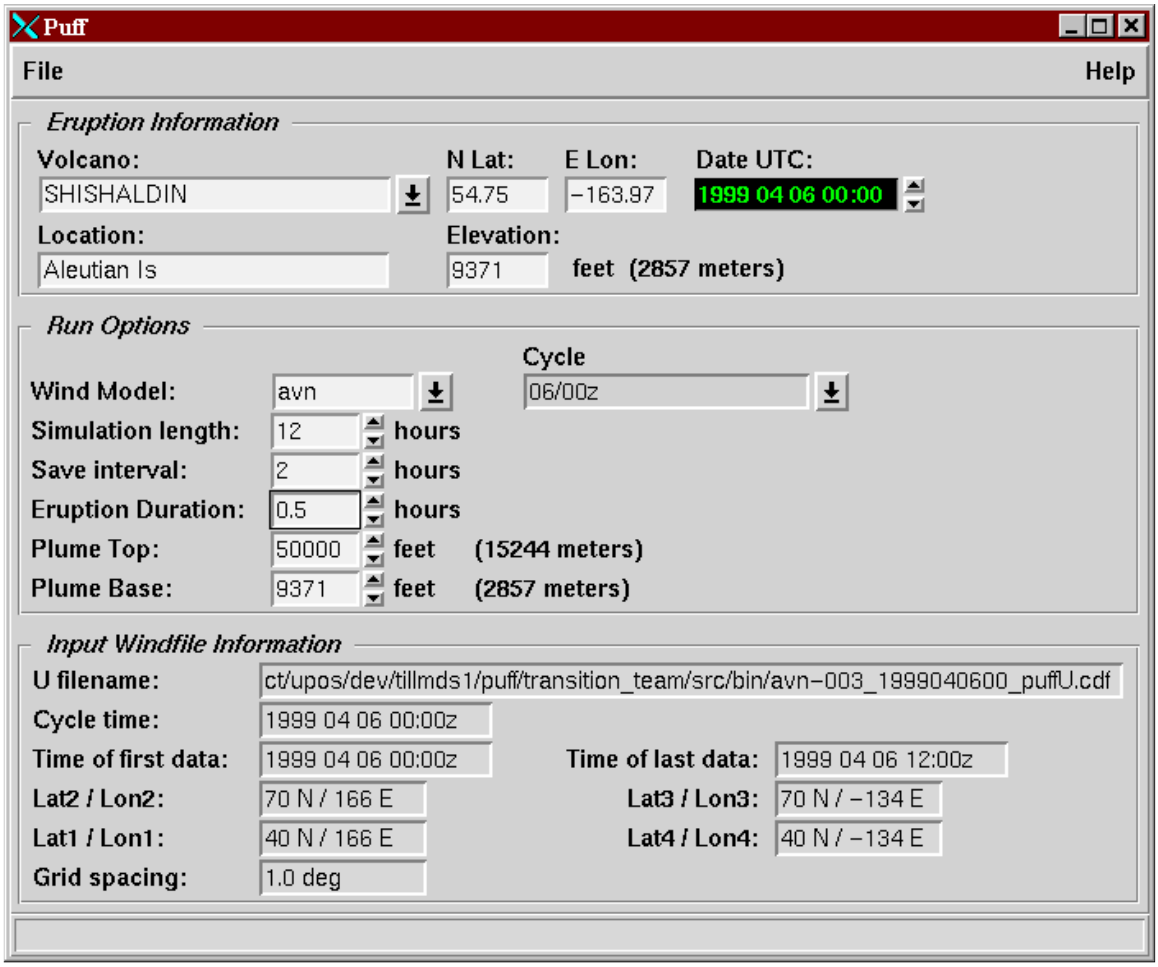

Figure 3 Final Puffgui Settings

3.4 Run Model

Select the File|Run… menu item. An informational dialog box containing a progress indicator will appear.

NOTE: During the PUFF model operation, you might see a warning dialog box stating that ash data are out-of-bounds. This means that one or more ash particles was projected to move outside the region of available wind data (the conversion for this example specified an area +/- 15 degrees in latitude and +/- 30 degrees in longitude). If you see this dialog, click on its button to acknowledge it. Execution will proceed with the ash files created to that point.

At the conclusion of the processing (typically < 1 minute), the “puffview” utility is automatically invoked with the output files from the PUFF run.

3.5 Display Results

When puffview is started, it initially loads a map image appropriate for the location of the volcano (Figure 4). This can take a couple of minutes depending on the level of detail desired in the coastlines. Once the map is loaded, the ash files output by the model are opened and listed in the list box in the top left corner and are automatically loaded. The ash displayed after all files are loaded in sequence corresponds to the data from the last file loaded.

Click on the “Loop” button to animate the ash progression from the first time to the last time. Click the same button (now labeled “Stop”) to terminate the animation with the conclusion of the next cycle. Note that you can position the mouse over any part of the map display and left-click to get a latitude/longitude readout in the bottom right-hand corner of the display window.

Click on a pushpin type such as "capital" to display all capital identifiers that are associated with that map area or click on an already displayed pushpin type to remove those items from the display map. Choose the "Tools|Pushpins Selection" menu item to hide or redisplay specific pushpins .

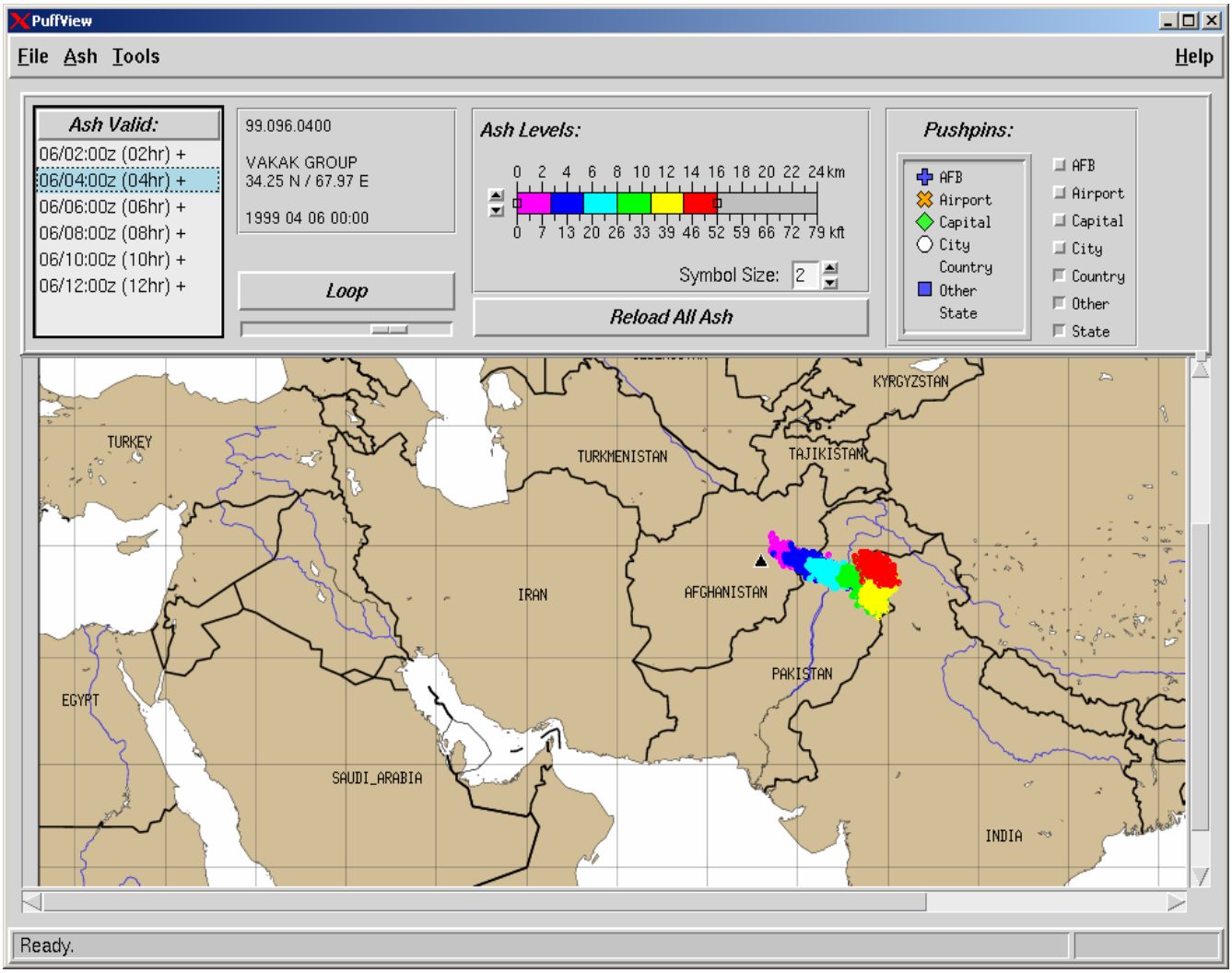

Figure 4 Puffview Window

Choose the File|Print menu item and enter the print queue name in the dialog box (or accept the default) to print a copy of the display.

When you're finished viewing the ash distribution, select the File|Quit menu item. This will terminate both puffview and puffgui.

4 PUFFGUI Operation

This Section describes the operation of, and options available within, the puffgui and afwa2puff dialog boxes in detail. Puffgui provides a GUI wrapper around the execution of the puff program. It allows the user to specify choices for the main execution options using selection and entry boxes, and to set any of the less-used options via a generic dialog box. Following specification of options, the user can invoke the PUFF model by choosing one of the File|Run menu options. A progress indication is provided while the puff executable is being run. After execution, puffview is started automatically, and all ash files produced as a result of that run are listed in the ash file list in the upper left corner of the display, loaded, and depicted in sequence on the map. Note that at any given time the contents of a single ash file are displayed. After automatic loading this will be the last file loaded. The user can click on any loaded file (as indicated with a '+' suffix) in the list and the contents of that file will be displayed.

If the user wants to change map options before loading the map, the user can choose the "File|Run w/ Map Options" menu item. This also runs the puff executable but instead of going right to puffview, the Map Options window is displayed. After making selections and choosing "Save & Map", puffview is started. This avoids the delay of loading the basemap twice (i.e. load basemap, make map options, load basemap again).

Note: After the first run when both puffgui and puffview windows are open, if the user wants to run the model again with different parameters (e.g., plume distribution), he can click on the puffgui window to make it active, make the appropriate changes, and re-run the model. Assuming that the volcano selection is not changed, this avoids the delay associated with creating the basemap in puffview.

4.1 PUFFGUI

The puffgui dialog box has three main sections of data plus two top-level menu options. The three main sections are 1) Eruption Information, 2) Run Options, and 3) Input Windfile Information. The menu options are File and Help. Each is now discussed in more detail.

4.1.1 Text Areas

4.1.1.1 Eruption Information

This section enables the user to select a volcano from a global list of volcanos and specify an associated eruption date and time. Alternatively, the user can type the name of the volcano exactly as it is given in the volcanos.txt file. In either of these cases, the latitude, longitude, location, and elevation information are automatically filled in. For the small number of volcanos in the list that lack elevation information, the word "unknown" in displayed in that field.

The user may also position the cursor in the volcano name entry box and type in the name of an unlisted volcano or location of interest. In that case, the user must also provide an associated North latitude and East longitude pair (both in decimal degrees). The Location and Elevation entry boxes are for information only, and their use is optional. Note, however, that by default for linear plumes, the elevation value is used for the plume base. This is a one-way linkage and the user may change the plume base value to whatever is desired without affecting the elevation displayed.

The volcano list is built at run-time from the file "volcanos.txt". Additional volcanos can be added to, or existing ones deleted from, this file. If additional ones are added, they should exactly follow the colon-delimited format in use.

The eruption date/time defaults to the current date/time. The speed at which time advances or retreats when the user holds the mouse button down with the pointer over the up or down arrows increases in four distinct steps after changing the time by a certain amount. The date advances by 10 minute steps for the first 3 hours, then by 1 hour for the next day, then by 1 day for the next 10 days, then by week and finally by month. Releasing the mouse button resets the step to the initial value. This process may be somewhat slow if the date needs to be changed many days. In such a case the better approach is to specify the date as a parameter on the puffgui command line:

```
%> puffgui –eruptDate "1999 04 06 00:00"
```

4.1.1.2 Run Options

This section enables the user to control the operation of the model.

4.1.1.2.a Model/Cycle

The first item, Wind Model, allows the user to specify the source wind model to use and the particular file. The combination of the Model specification and the selection of a date/hour starting time uniquely identifies a PUFF input file based on AVN, NOGAPS, or Datacube sources. When the MM5 model type is selected, the Cycle combobox displays the theater and nest of the file as well as the date/time. For example, a file containing data from theater 3 and nest b might display "t3/b 04/00z".

Once the model is specified, the program searches the directory specified by the "path" option for any applicable files. The search process looks for filenames with a certain organization, as defined in the puff.args file for each of the types of files supported. If files meeting the description are found in the directory specified by the "path" option (default is current directory), their "cycles" (date/hour of the associated model run), are listed in the Cycle combo box. When you select one of these, details of the file contents (in particular, time and lat/lon extents) are displayed in the "Input Windfile Information" section. Note that you cannot type directly into the Cycle combo box; you must select one of the choices the program derived from files found on scanning the directory specified by the path option.

4.1.1.2.b Simulation Length

Simulation length is one determinant of the time period analyzed by the model. The program starts with the eruption date/time and models ash movement for the next "Simulation length" period. Actual granularity of the simulation (the times at which ash locations are computed) is determined by the "dtMins" option and is defaulted to five minutes.

Although the Simulation Length Control Widget steps by hour increments, the user can directly enter fractional times (e.g., 2.5 hours). Note also that the Simulation Length, Save Interval, and Eruption Duration controls are linked and automatically constrain entries to viable choices. For example, if the user were to decrease the Simulation Length value to less than the Save Interval, the Save Interval will automatically decrement so as to never be longer than the Simulation Length.

4.1.1.2.c Save Interval

The times at which ash locations are saved to a file are determined by the "Save interval" parameter. That is, ash migration is determined at a fine resolution (dtMins) but the time interval at which you see the results is determined by the "Save interval" option. Save interval values are currently limited to integer values.

4.1.1.2.d Eruption Duration

The "Eruption Duration" parameter is the period of time in hours that the volcano erupted. If the volcano is erupting continuously, this should be equal to the "Simulation length" value. Eruption time can be adjusted in increments of tenths of hours using the control or times can be directly entered by the user.

4.1.1.2.e Plume Top and Plume Base

The "Plume Top" and "Plume Base" parameters' meanings differ based on the vertical ash distribution selected. Please see Section 4.1.1.1.a, Plume Distribution, for details.

4.1.1.3 Input Windfile Information

This section displays a summary of the contents of an input windfile (if one has been selected through the Model/Cycle entry combination) and is not editable by the user. This shows the path of the file being accessed; the file cycle, start, and end times; the latitude/longitude of the four corner points of the grid coverage; and the grid spacing.

The cycle reflects the date/time of the model run that was used as the source for the data. The start time reflects the time of first data in the Puff file. The end time is the time of last data in the file. Normally the start time and cycle time will be the same. The

exception occurs most frequently with MM5 subnests, where the first forecast time for the subnest is some number of hours later than the cycle.

PUFF input files derived from global lat/lon data will contain a relatively small subset of the data contained in the collection of GRIB forecast files. The GRIB files for the AVN and NOGAPS data are based on a 1 degree lat/lon spacing, and would result in extremely large PUFF input files if converted in toto. Since a user is usually interested in the area immediately around a volcano, the default is to convert a +/- 15 degree latitude by +/- 30 degree longitude range. Thus the input file produced for an Alaskan volcano will not cover a Mediterranean volcano. The program will check for adequate coverage and will prevent processing with incorrect data.

PUFF input files derived from cartesian grids will contain all the data points represented by the grid.

4.1.2 Menu Options

4.1.2.1 Menu Operation

The menus used by puffgui are “tearoff” capable menus. The dashed gray line that appears just under the menu option when selected indicates this characteristic. The user can either operate the menu the conventional way (click on the top level when you need it and then select from the drop-down list), or tear the menu off and have it exist as a separate window. To do that, click on the top level menu to cause the menu list to appear. Then move the mouse pointer to the dotted line, press the left button, and drag to the desired location. Release the mouse button and the menu will remain as a separate window.

If a menu item is elided, it means that another level of user interaction will occur before any program action. That is, another dialog box of some form will be presented for further action by the user.

4.1.2.2 File

4.1.2.2.a Run ...

The Run selection causes the puff program to be run, and following successful completion of that, causes the puffview program to be run. If the programs should fail for any reason (e.g., input files with illegal data), a log file is displayed that lists the values of the parameters for that run.

4.1.2.2.b Run w/ Map Options ...

The "Run w/ Map Options ..." selection also causes the puff program to be run, and instead of going right to puffview, the Map Options window is displayed. After making selections and choosing "Save & Map", the puffview program is executed. This allows the user to change map options before loading the map, thus avoiding the delay of loading the basemap twice (i.e. load basemap, make map options, load basemap again). If the programs should fail for any reason (e.g., input files with illegal data), a log file is displayed that lists the values of the parameters for that run.

4.1.2.2.c Run Multiple Eruption ...

The "Run Multiple Eruption ..." menu item is used to run a puff simulation with more than one eruption. Puff can simulate multiple eruptions from either the same volcano or from different volcanos. The new eruption is based on an existing ash file which describes the previous eruption(s). This existing ash file must be present in the file system to run a multiple eruption. If it is not, one can be generated using either of the File menu selections "Run ..." or "Run w/ Existing Cloud ...".

Perhaps you are tracking activity on Mt. Etna, for example, which has an initial eruptive event, is docile for several hours, and then erupts again. In order to simulate this event, you begin Puff with the initial eruption using the File menu selection "Run ..." (or "Run w/ Existing Cloud ..." if you have remote sensing data that describes the initial ash cloud), and then "add" the second eruption when it happens using "Run Multiple Eruption ...".

For the initial eruption, set the "Save Interval" and "Simulation Length" Run Options such that an ash file will be generated at the closest possible time to the second eruption. For example, if the first eruption occurs at 00:00 hrs, and the second eruption occurs at 12:05 hours, then we would ideally like to generate an ash file with timestamp 12:05 hours. Since puffgui only allows save intervals at one hour increments, the nearest time for which we can generate an initial ash file is 12:00 hours. Setting the Simulation Length to at least 12 hours and the Save Interval to any divisor of 12 will suffice for the initial eruption. This will generate an ash file with the name *1200_ash.cdf., where * is the date of the eruption. Then, to run the multiple eruption, choose the parameters for that eruption, making sure to reset the eruption time appropriately. Select "Run Multiple Eruption ..." and select the *1200_ash.cdf file when prompted. If the eruption time shown in the GUI does not match the time stamp of the selected ash file, you will be notified.

Both the ash file and the volcano must be covered by the wind file to run the multiple eruption. If needed, run the GRIB conversion with a wider longitude/latitude range to cover both the volcano and the existing ash cloud from the first eruption.

4.1.2.2.d Run w/ Existing Cloud ...

The "Run w/ Existing Cloud ..." menu item is used to track an existing ash cloud. If remote sensing or satellite data of an existing cloud is available, puffgui's Cloud Editor tool (4.1.2.2.f) can be used to create a puff-readable cloud file describing the geometry and density of the cloud. Puff can then be run using this information by selecting the appropriate parameters for the simulation then selecting "Run w/ Existing Cloud ...". After selecting this menu item, you will be prompted to open the existing ash cloud file, which must exist in the file system. The main puff GUI will be updated with the cloud longitude and latitude. If the wind data does not cover the cloud, you will be notified and may perform a GRIB conversion using the longitude/latitude that is displayed for the cloud.

A cloud file can be generated manually but the Cloud Editor is recommended for this task. The editor runs several tests to validate the format of the cloud file. The format and restrictions of the cloud file as well as additional information can be found in section 5.1.1.3(ii).

When running puff using "Run w/ Existing Cloud ...", the "Eruption Duration" setting is ignored.

4.1.2.2.e Run New Eruption w/ Existing Cloud ...

The "Run New Eruption w/ Existing Cloud ..." menu item is used when you wish to track an existing ash cloud described by remote sensing data and a new eruption occurs. You can also simulate this scenario using "Run Multiple Eruption ...", but perhaps your remote sensing or satellite data indicates that such a simulation didn't adequately track the ash from the first eruption. In that case, "Run New Eruption w/ Existing Cloud ..." would be the best way to track the new eruption.

Before you select "Run New Eruption w/ Existing Cloud ...", you must specify a volcano name and set any other parameters, in particular the eruption date, for the new eruption. You will then be prompted to open an existing ash cloud file which describes the ash cloud at the time of the new eruption, and which can be generated with the Cloud Editor prior to selecting "Run New Eruption w/ Existing Cloud ...".

Both the existing cloud and the volcano must be covered by the wind file to run the new eruption. If needed, run the GRIB conversion with a wider longitude/latitude range to cover both the volcano and the existing ash cloud.

4.1.2.2.f Cloud Editor …

The "Cloud Editor …" menu item brings up a GUI containing a map and an editing toolbar to the left of the map, Figure 5.

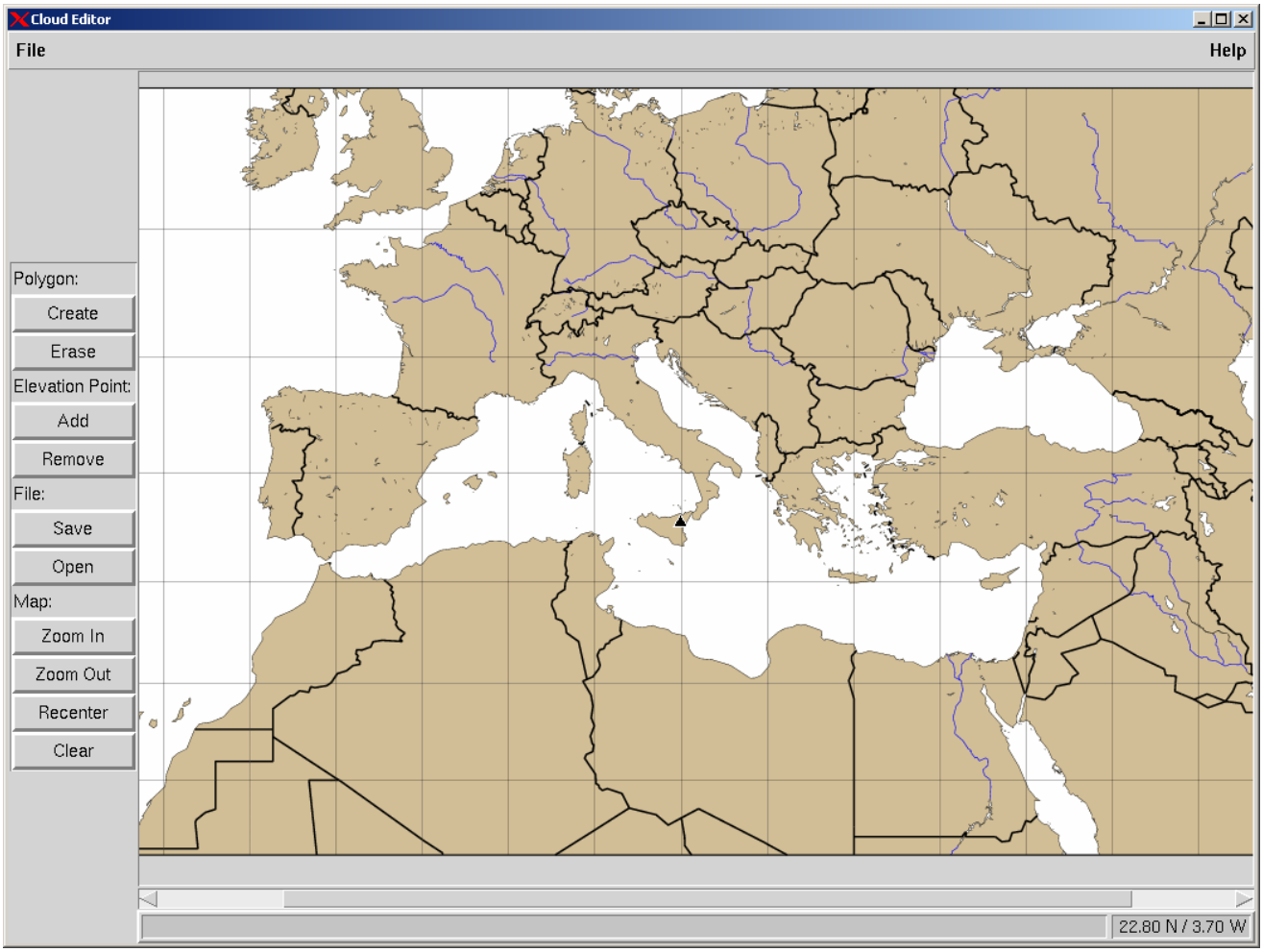

Figure 5 Cloud Editor

The Cloud Editor is used to generate files describing the geometry and ash density of ash clouds which can then be tracked using puffgui in one of the two operation modes used for simulating the movement of existing ash clouds (see sections 4.1.2.2.d and 4.1.2.2.e above). A volcano name must be entered in the main GUI to run the Cloud Editor. The Cloud Editor map will be centered on the volcano. If you wish to recenter the map on a different volcano once the Cloud Editor is already up, it is generally quicker to go back the main puff GUI, select the new volcano, and re-open the Cloud Editor than it is to use the *Recenter* toolbar button.

The ash cloud is defined by a polygon outline and interior elevation points. The polygon outline is defined by longitude/latitude pairs describing the vertex points. The elevation points are defined by longitude/latitude/elevation triplets and describe the density of the ash at a given elevation. To create an area of greater density of ash particles, add more elevation points to that area. Puff will distribute the ash particles

evenly around the elevation points. Section 5.1.1.3(ii) describes the ash cloud file in greater detail.

The elevation points must be inside the bounds of the and no line segments in the defined polygon may intersect, so a figure-8 is an invalid polygon shape. No polygon may span an area greater than 180 degrees. No more than one polygon may be created in the cloud editor at a given time. The Cloud Editor will notify you if an invalid case exists. A snapshot of a cloud generated with the Cloud Editor is shown in Figure 6.

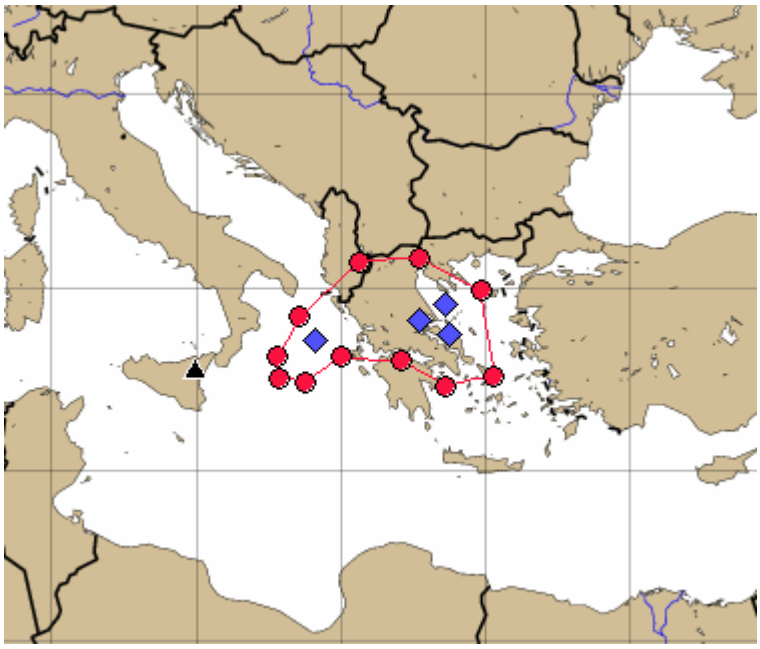

Figure 6 Ash Cloud Generated with Cloud Editor

Create a new polygon by pressing the *Create* button on the toolbar, then clicking on the map using the left mouse button to define the vertices of the polygon. This will disable the toolbar buttons. Continue clicking until the polygon is complete. A polygon is defined by a minimum of 3 vertices. Red circles will appear on the map to represent the vertices of the polygon, and red lines will appear between consecutive vertices to define the segments connecting the vertices. To close the polygon, press Ctrl-c on the keyboard. This will re-enable the toolbar buttons. If less than 3 vertices have been created when you close the polygon, you will be prompted to continue adding vertices. Erase a polygon by pressing the *Erase* toolbar button.

Create an elevation point by pressing the *Add* toolbar button, then clicking on the map at the location of the elevation point. A dialog box will pop up to prompt you to enter the elevation at the longitude/latitude at which you had clicked the mouse. If a non-negative integer elevation is entered, a blue diamond representing the elevation point will appear on the map. Press the *Remove* button then click on an existing elevation point to remove it. To view the elevation of an existing elevation point, right-mouse-click on the elevation point.

Clouds must be saved to file before they can be used in running Puff. Cloud files may also be opened for viewing and editing. Cloud files can be saved (opened) using either the *Save (Open)* toolbar button or the "Save" ("Open") item in the "File" drop-down menu at the top left of the screen. The Cloud Editor must be clear of any drawings (polygons and/or elevation points) before it can open a file for display.

When saving a cloud file, the Cloud Editor will notify you if the cloud you created is invalid. If any of the elevation points are outside the polygon, you will be notified and asked if you wish to have them automatically deleted before saving the cloud. If all of the elevation points lie outside the bounds of the polygon and you choose to have them deleted, you will not be able to save the cloud unless you add at least one new elevation point inside the polygon.

When opening a cloud file for viewing or editing, you will be prompted to erase any existing clouds. If the cloud that is being opened is not in the range of the displayed map, the Cloud Editor will recenter the map to the cloud location.

The map can be zoomed and recentered by pressing the appropriate button then clicking on the map. The *Clear* button is used to erase all polygons and elevation points from the map. It is equivalent to pressing the *Erase* button then removing each elevation points by repeatedly using the *Remove* button.

Exiting the editor by selecting the "Exit Editor" File menu item at the top left of the screen will close the editor and return you to the main puff GUI.

A cloud file can be generated manually but the Cloud Editor is recommended for this task. The editor runs several tests to validate the format of the cloud file. The format and restrictions of the cloud file as well as additional information can be found in section 5.1.1.3(ii).

4.1.2.2.g Log …

Selection of this menu item allows the user to view the contents of the log file of the most recent run.

4.1.2.2.h Options …

The "Options …" menu item brings up the options dialog shown in Figure 8. This provides the advanced user with a method for specifying normally defaulted model parameters to better reflect the operational environment.

4.1.2.2.i GRIB convert …

This option supports the conversion of GRIB files on lat/lon and XY grids to the netCDF format required by puff. Selecting this option brings up an additional dialog box (Figure 7) that allows specification of the source wind model; minimum and desired

number of hours of data; latitude/longitude range around the volcano for which data will be converted (lat/lon case); and theater and nest selection for the MM5 case. Nominally the lat/lon range extends +/- 15 degrees in latitude and +/- 30 degrees in longitude. If the volcano location about which this range is centered is far enough North or South, the latitude range may extend over the pole. In such a case, complete longitude (360 degree) coverage is automatically assumed by the conversion program. Note that this greatly increases resultant file size. For non-lat/lon-based grids, all data are converted.

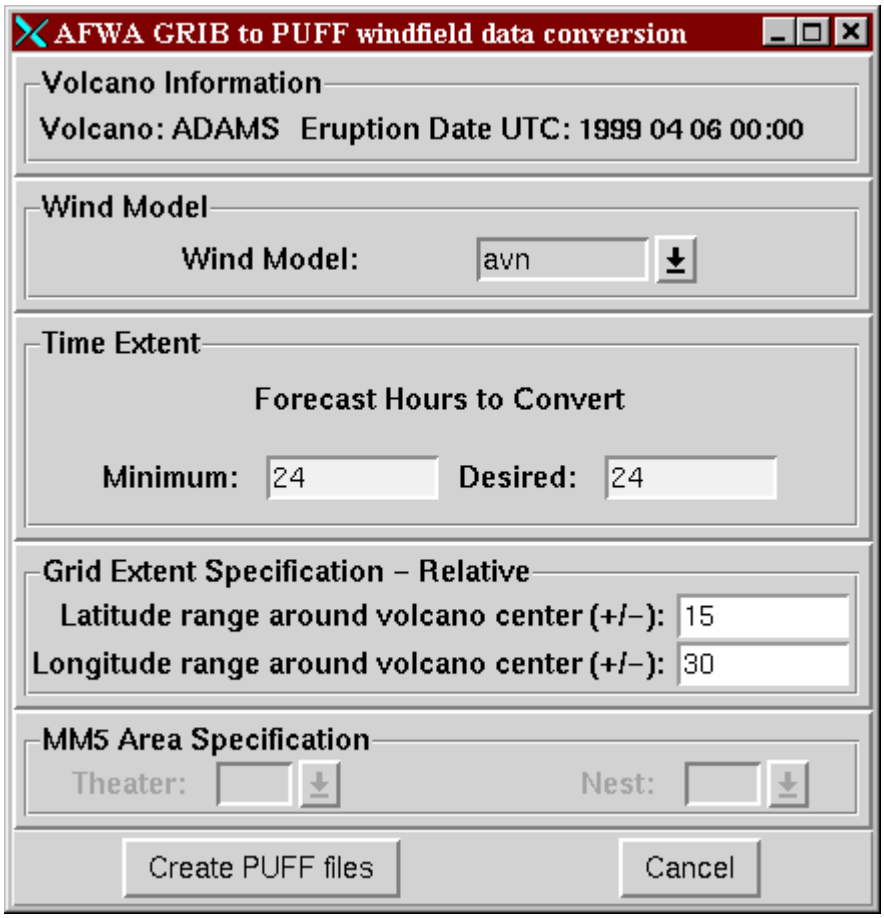

Figure 7 GRIB Data Conversion Dialog Box

If the user selects a wind model that uses lat/lon grids, the "Grid Extent Specification – Relative" entry frame is active and the "MM5 Area Specification" widgets are inactive. If the user selects the MM5 model choice, the lat/lon area becomes inactive and the MM5 Area Specification becomes active. The program dynamically builds the list of available theaters each time it runs based on the presence of theater directories in the MM5 parent directory. When the user selects a theater, the program dynamically builds the list of available nests based on the files present in the directory.

The user can also specify the minimum and desired number of hours of forecast data to convert. These values can range from 1 to 72 hours (assuming that 72 hours of

forecast data are available) and are 24 hours by default. The source GRIB files cover a single forecast time each; the step size varies depending on the model. For example, NOGAPS provides forecast data on three hour intervals, while MM5 may provide forecasts on 1 hour intervals. The program displays an error message when the requested minimum number of hours of wind data goes beyond the range of the wind model data. The message will indicate the time of the last wind data. When the minimum number of hours is met but the desired number of hours is not, the program proceeds by converting as much wind model data as there is.

The program determines the starting forecast time by picking the latest forecast cycle that is equal to or earlier than the eruption time. So for an eruption on "1999 04 06 11:59", the program would start converting with the "1999 04 06 00:00" cycle (assuming a twice-daily model run). The actual number of hours to be converted may be more than that requested because the program understands the user's intent to have coverage for a number of hours beyond the initial eruption. If the combination of the user-specified minimum number of hours to convert and the number of hours between the eruption time and the most recent forecast cycle exceeds the coverage of forecast files currently available for that cycle, the program will continue searching for earlier cycles to meet the request. If no cycles can satisfy the minimum specification, a dialog box is displayed alerting the user to the situation and the conversion is terminated. The "desired number of hours to convert" is used as a goal for the program, and to the extent files are available beyond those required to meet the minimum criteria, it will process those files.

NOTE: Conversion of GRIB windfield data to puff input data can be performed on an automatic basis using the Unix "cron" facility. In that case, the user simply selects the input file covering the volcano and time period of interest in the puffgui main dialog box.

4.1.2.2.j Quit

Selection of this menu item causes puffgui to terminate.

4.1.2.3 Help

4.1.2.3.a on Version

This menu option identifies the history and current version of the program.

4.2 PUFF Alternative Option Specification

4.2.1 Methods

Options for puff and associated utilities can be specified via command line arguments and/or text input file, in addition to via the dialog boxes. Available options can be listed on the screen via the following command:

```
%> puffgui –help
```

To specify parameters on the command line during startup, simply pair the option with the desired value. Desired values should always be enclosed in double quotes. Values must be separated from the option by one or more blank spaces. For example:

```
%> puffgui –eruptDate “1999 04 06 00:00”
%> puffgui –path “./partial”
%> puffgui –plumeHwidth “0.5”
```

Commonly specified parameters can be placed in a text file according to the following format:

```
\<option name> “option value”
```

For example:

```
\volc “SHISHALDIN”
\volcLon “196.03”
\avnPath “/project/upos/puff/avn/”
```

Then you need to specify the name of this options file on the command line when the function is invoked:

```
%> puffgui –argFile “puff.input”
```

This will set the initial values for the options you specify. A subset of these values can be altered if desired from within puffgui by selecting the File|Options… menu item from the main dialog. The options dialog (Figure 8) has a combo box that allows selection of any of the options. Once one has been selected, enter the desired value in the text entry box. If this option has a default value, it will be displayed on the “Default” line. The “Comment” line provides a short explanation of the value. If an option has a value (set by default or by operator specification), the value will be displayed in the “Value” text entry box. Note that the set of options accessible via this means has been generally limited to those related to model parameters.

You can iteratively select options and set values until all desired options have the desired values. Then click the SAVE button to save the results.

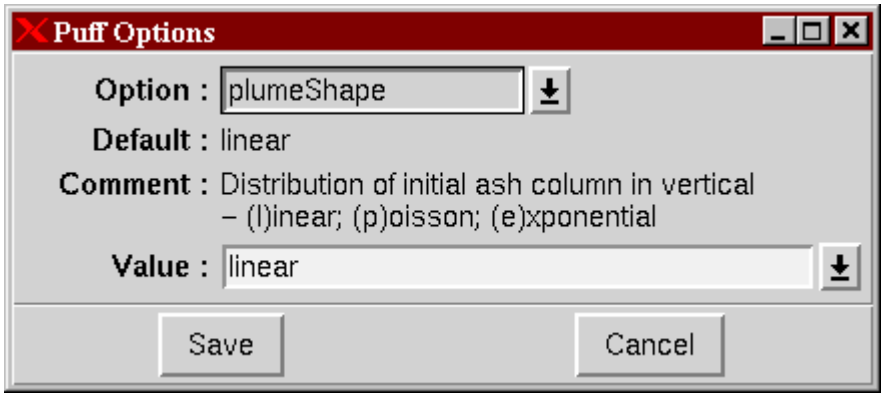

Figure 8 Options Dialog

4.2.2 Options

Table 2 Options List contains a complete list of options that can be specified for puffgui on the command line or in a text file. **Options that can be set from the "Options" dialog box in puffgui are given in bold italics.** Please note that although the user interface has been designed to allow elevation/altitude specification in units of feet, the puff program uses units of meters internally, and options specified in files or on the command line need to be in units of meters.

Table 2 Options List

Option	Description	Default
volc	Volcano name	"unknown"
volcLon	Volcano longitude (decimal degrees East)	-9999
volcLat	Volcano latitude (decimal degrees North)	-9999
eruptDate	UTC Eruption date string in format "YYYY MM DD HH:MM"	""
runHours	Simulation length (hours)	24
saveHours	Save ash output at every saveHours interval (hours)	6
eruptHours	Continuously emit ash particles over this duration (hours)	24
dtMins	Step time interval (minutes)	5
path	Puff input wind file directory path	"."
nAsh	Number of ash particles initialized and tracked	3000
plumeMax	Maximum plume height in meters when plumeShape = linear	16000
plumeMin	Minimum plume height in meters when plumeShape = linear	0
plumeShape	Distribution of initial ash column in vertical – (l)inear; (p)oisson; (e)xponential	"linear"

Option	Description	Default
plumeZwidth	Initialize ash vertical spread in meters	3000
plumeHwidth	Initialize ash horizontal spread in meters	0
diffuseH	Horizontal diffusion coefficient (m^2/integration period)	20000
diffuseZ	Vertical diffusion coefficient (m^2/integration period)	10
AshLogMean[1]	(See explanation following table)	-5
AshLogSdev[1]	(See explanation following table)	1
saveAshInit	Save the initial ash state if true	0 (false)
runSurface	Continue tracking particles at z=0 if true	0 (false)
noFallout	Do not include fallout in the ash particle motion	0 (false)
saveWfile	Save the divergence-created vertical wind to a file	0 (false)
argFile	Name of file from which to read optional arguments	""
quiet	Do not print time value after each time step	0 (false)
newline	Write newline after each time step	0 (false)
verbose	Make verbose output	0 (false)
help	Print this summary	0 (false)
avnPath	AVN model GRIB file parent directory path	<your path>
nogapsPath	NOGAPS model GRIB file parent directory path	<your path>
volcPath	Volcano list filename	"<your puff installation path> /src/volcanos.txt"
restartFile	Filename of either an existing ash file from a previous puff run (for multiple eruption) or filename of a cloud file describing an existing ash cloud (for run with existing cloud).	""

Notes:

(1) The ash particle size distribution is gaussian on a *logarithmic* scale. That is, by default, the peak of the gaussian curve is at –5, representing an ash particle radius of 10^{-5} meters. The standard deviation *on the logarithmic scale* is 1, meaning that 60% of the particles will be between –4 and –6 on the scale, corresponding to sizes between 10^{-4} and 10^{-6} meters.

5 PUFF Operation

The PUFF volcanic ash dispersion model is implemented in the "puff" executable. Following are descriptions of its inputs and outputs and some discussion of the processing that takes place.

5.1 Inputs

§ U windfield data (velocity in m/s) in netCDF format (vs. time/level/lon/lat)
§ V windfield data

§ Command line options (if present)
§ Text file containing option specifications (if present and identified via a command-line argument)

The command line options (and consequently, the possible options to be included in the options input file) are the same as for puffgui. Assuming that you have specified some options in a text file named "puff.input" (in the directory in which you invoke puff), the following command would invoke puff and cause it to read "puff.input" to determine the desired options:

```
%> puff –argFile "puff.input"
```

Puff looks for input windfield data in the directory specified by the "path" option. By default this is the current directory (one in which you invoked puff). This can be changed by specifying the –path <pathname> option on the command line or by specifying the path in the option file.

The names of the input wind files are reflective of the time of the forecast cycle upon which they are based. For example, the following file contains U windfield data from the 0000z, April 6, 1999 cycle, and produced by the AVN model on the NCEP #3 grid:

```
avn-003_1999040600_puffU.cdf
```

Windfield files' geographical area of coverage may vary. The coverage can be determined by using the netCDF utility "ncdump" to dump selected information from the file. You can determine the geographic extent covered by the data from this file using the following command:

```
%> ncdump –v latitude1,longitude1,latitude2,longitude2,\
latitude3,longitude3,latitude4,longitude4 \
avn-003_1999040600_puffU.cdf
```

The variables being dumped (those in the list) must be comma-delimited and not have any spaces in the list.

5.1.1 PUFF Modeling Options

Options that affect the behavior of the model are discussed in the following subsections.

5.1.1.1 Options Determining the Initial Plume Characteristics

5.1.1.1.a Plume Distribution

The following options affect the initial plume distribution (i.e., the x,y,z location of each of the modeled ash particles at the beginning of the eruption):

plumeShape
plumeHwidth
plumeZwidth
plumeMax
plumeMin

(i) Vertical Characteristics

The plumeMax ("Plume Top" in the puffgui window) and plumeMin ("Plume Base" in the puffgui window) parameters' meanings differ based on the vertical ash distribution selected. The three possible cases are now discussed.

(a) Linear Ash Distribution Case (default)

plumeMax corresponds to the maximum height of the ash. plumeMin corresponds to the minimum height of the ash. The sample ash particles are distributed using a random function with a uniform probability distribution function over the desired range.

(b) Exponential Ash Distribution Case

plumeMax represents the approximate top of the ash. plumeMin is not used. The following formula is used to place sample ash particles in the vertical distribution:

Spread = 0.25 * plumeZwidth * rand
Ash particle height = plumeMax – (plumeZwidth * expdev) + spread

where: *plumeZwidth* represents an approximate vertical range over which the ash will be distributed (default: 3000 meters)
rand is a uniformly distributed random number (0,1)
plumeMax is the approximate top extent of the ash (meters)
expdev is a positive random number from an exponential distribution of unit mean

(c) Poisson Ash Distribution Case

plumeMax represents the approximate top of the ash. plumeMin is not used. The following formula is used to place sample ash particles in the vertical distribution:

Spread = 0.5 * plumeZwidth * rand
Ash particle height = plumeMax – (plumeZwidth * poidev) + spread

where: *plumeZwidth* represents an approximate vertical range over which the ash will be distributed (default: 3000 meters)
rand is a uniformly distributed random number (0,1)
plumeMax is the approximate top extent of the ash (meters)
poidev is an integral value drawn from a Poisson distribution of unit mean

(ii) Horizontal Characteristics

plumeHwidth affects the horizontal distribution of the ash particles. It uses a uniformly distributed random process to determine the ash particle location in a circle of radius plumeHwidth (*at the plumeMax height*) centered on the volcano site. NOTE: The horizontal distance that the ash is displaced from the cone is determined by taking the results of the random offset determination and multiplying them by the ratio of the height of the particle to the top of the plume. So the net shape of the plume is an inverted cone, where particles are located directly over the volcano at the lowest level and extend out farther horizontally with increasing plume height.

5.1.1.1.b Plume Size

The following options affect the size of the ash particles:

logAshMean
logAshSDev

The ash particle size distribution is gaussian on a logarithmic scale. That is, by default, the peak of the gaussian curve is at –5, representing 10^{-5} meters. The standard

deviation on the logarithmic scale is 1, meaning that 60% of the particles will be between –4 and –6 on the scale, corresponding to sizes between 10^{-4} and 10^{-6} meters.

5.1.1.1.c Plume Population

The following option determines the number of ash particles created:

nAsh

The total number of ash particles created and tracked by the simulation is set by the value of the nAsh option. This number is 3000 by default. Note that particles from this set "appear" uniformly distributed in time over the duration of the defined eruption duration. For example, if the eruption duration is 30 minutes, and the integration time (dtMins) is 5 minutes, then roughly 1/6 of the 3000 particles, or 500, will be introduced in a given integration period. If the eruption duration is 48 hours, then approximately five particles will be introduced during each integration period, and if the save interval is set to an hour, the first ash file will only reflect the modeling of about 60 particles.

5.1.1.2 Options Controlling Model Execution

The following parameters affect model execution:

dtMins
noFallout
runSurface
diffuseH
diffuseZ

The dtMins parameter specifies the time step in the modeling process. For example, with the default value of 5 minutes for dtMins, the simulation will a movement value for each particle for every 5 minute period of the simulation duration (assuming that particle has not hit the ground).

The noFallout option allows the user to disable one of the three effects being applied by the model, that of gravitational fallout. If this is disabled, the only effects acting on the particles are advection and diffusion.

The runSurface flag, if set to 1 (true), will cause the simulation to continue tracking the movement of ash particles whose height is 0 meters.

The diffuseH parameter affects the horizontal diffusion modeling, and ultimately, the horizontal spreading of the ash particles. The diffuseZ parameter influences the vertical movement of the ash. In both cases, equations ultimately determine a distance in meters and a direction of movement for each ash particle in each integration step. The equations are:

ch = sqrt ((2.0 * diffuseH) / (integration time in seconds))
cv = sqrt ((2.0 * diffuseZ) / (integration time in seconds))

Then for each particle in each integration step:

movement in X direction = ch * (unit mean gaussian random variable) *
(integration time in seconds)
movement in Y direction = ch * (unit mean gaussian random variable) *
(integration time in seconds)
movement in Z direction = ch * (unit mean gaussian random variable) *
(integration time in seconds)

5.1.1.3 Option Describing a Multiple Eruption or Ash Cloud Tracking Simulation

The restartFile option is used to set either the ash file describing the previous eruption in a multiple eruption or an ash cloud file if puff is being used to track the movement of an existing ash cloud. To run a multiple eruption simulation, a puff-generated ash file describing the previous eruption must exist in the file system. To run a simulation tracking an existing ash cloud, a file describing the ash cloud must exist in the file system. The format of this file is described below.

(i) Multiple Eruption

Puff can simulate multiple eruptions from either the same volcano or a different volcano. There is no pre-set upper limit to the number of eruptions, but memory restrictions obviously apply. Perhaps you are tracking activity on Mt. Etna, which has an initial eruptive event, is docile for several hours, and then erupts again. In order to simulate this event, you begin Puff with the initial eruption, and then "add" the second eruption when it happens using the -restartFile option. First simulate the initial eruption

%> puff -volc ETNA -eruptDate "2002 09 25 01:00" -eruptHours 1 -runHours 5 -saveHours 1

Then add the second eruption while loading in the data from the initial eruption in order to continue tracking it. Note that the volcano must be specified for the restart run or puff will not generate the new eruption.

%> puff -volc ETNA -eruptDate "2002 09 25 06:00" -eruptHours 1.5 –restartFile “02.268.0600_ash.cdf”

If the restart file timestamp does not matche the next eruption time(-eruptDate), as warning is issued but the simulation continues.

(ii) Ash Cloud Tracking

Puff can also be used to simulate the movement of an existing ash cloud. Perhaps you have remote sensing or satellite data that indicates there is an existing ash cloud east of Mt. Reventador, Ecuador. At 12:00 hours, the cloud is rectangular with higher elevation ash near the southern end but is denser near the northern end. You can use that information to initialize Puff using the -restartFile option. The execution will look like

```
%>  puff -eruptDate "2002 09 25 12:00" –restartFile reventador.cld
```

The restart file contains longitude/latitude pairs that define a polygon outlining the ash cloud, with interior points giving approximate elevation of the ash. The format of the restart file is

```
################################################
# Restart file reventador.cld
################################################
# All field have a XML-like structure, and can occur in any order.

# Polygon vertices (lon/lat)
<vertices>
283.0  0.0 # This is a comment after a vertex specification.
283.5  0.0
283.5 -1.0
283.0 -1.0
# The field must be closed before another can be opened.
</vertices>

# Elevation points  (lon lat elevation[m])
# There can be one or more and must reside within the polygon defined above.
# Repeating elevation points add more weight to that area of the cloud.
<elevations>
283.3 -0.1 10000
283.3 -0.1 10000
283.3 -0.1 10000
283.3 -0.3 12000
283.3 -0.5 14000
283.3 -0.7 16000
283.3 -0.9 18000
</elevations>
################################################
```

The # symbol indicates a comment. Longitudes are written in degrees East and Latitudes in degrees North. Elevations are in meters. Blank lines and excess spaces are ignored. No line segments in the defined polygon may intersect, so a figure-8 is an invalid polygonal shape. The vertices must be written in consecutive order, i.e. the order in which they would be drawn. Randomly written vertices may give unexpected results. The cloud file must contain at most one polygon and at least one elevation point. All

elevation points must reside within the polygon. Puff will distribute the ash particles evenly around the elevation points. To create an area with a greater density of particles, add more elevation points to that area. Finally, a cloud cannot span more than 180 degrees.

When running puff in this mode with an existing ash cloud file, puff ignores the –eruptHours and –plumeMin options if set.

The algorithm that generates the ash cloud from the polygon and elevation points creates the ash by randomly walking from each elevation point and placing a new ash particle at each step unless it crosses the boundary of the polygon, in which case it goes back to the prior step and repeats the step in a random direction. An equal number of ash particles is allotted to each elevation point, with any remained added to the last elevation point.

If the initial ash cloud tracking simulation does not adequately describe the ash cloud, you may need to modify the cloud shape or elevation points. Results will also vary depending on the random number seed that is used in puff (this value can be set by calling puff or puffgui with the –seed option), so rerunning with a different will produce different results.

(iii) Re-eruption While Tracking an Existing Ash Cloud

Perhaps you have remote sensing data and are tracking an existing ash cloud from an earlier eruption of Mt. Reventador when a new eruption of the volcano. In this case, you would use the restart option as above, but include the option specifying the volcano name. If the new eruption occurs at 12:00 hours, call puff with the following command.

```
%>  puff -eruptDate "2002 09 25 12:00" –restartFile reventador.cld –volc
REVENTADOR
```

The format of the cloud file is described in the section above. Notice that the only difference between this call to puff and the ash cloud tracking call in section (ii) above is the appearance of the –volc option. When puff sees the volcano name specified, it runs a new eruption of the volcano while tracking the ash cloud specified by the restart file. Optionally, you may use the –volcLon and –volcLat arguments in place of –volc. The number of ash are evenly divided between the new eruption and the existing ash cloud.

5.2 Processing

The puff program begins by reading the U and V windfield data and deriving W windfield data (vertical winds) using a technique known as “divergence.” It then generates an initial ash plume based on default values or options specified by the user.

Following the initialization of the ash plume, the program begins an iterative process. Starting at the eruption time, and stepping "dtMins" minutes for each iteration, it considers a number of physical effects on each ash particle and "moves" each particle accordingly. When time has advanced "saveHours" hours since the beginning of processing, a snapshot of the ash particle locations is captured in a single ash file. Processing then resumes in the same fashion until the requested simulation duration has been satisfied.

With each iteration, each ash particle's new location is compared against the geographic extent of the wind data. If a particle's new position puts it outside that area, a message is displayed to the user that the ash is out of bounds, and processing is terminated following completion of that time step.

Actual computation of expected ash movement involves computing effects due to diffusion, advection, and ash fallout. The user can adjust some of these effects by modifying default values in the options, described in the previous section.

5.3 Outputs

- Ash location data in netCDF format (one file per saveHours interval per run)
- Progress indications displayed on screen indicating time in simulation and ash files written

When puff is run, it produces netCDF files containing ash data. The ash files are named according to the following format:

YY.DOY.HHMM_ash.cdf

For example, the following file contains data for the 96th day of 1999 at 0400z:

```
99.096.0400_ash.cdf
```

Additional information about the contents of the file can be obtained by using the "ashdump" utility described in Section 7.

The ash files are written to the local directory (i.e., the directory from which puff was invoked).

6 PUFFVIEW Operation

Puffview provides a means to display the resultant ash distribution on a map. It allows the user to select the ash files to display, choose the characteristics of the underlying (base) map, choose the ash height-color mapping for the particles and choose which location identifiers (pushpins) to display. It allows the user to save the map and overlay graphics of the simulation in postscript, gif, and chart form.

Puffview is invoked automatically by puffgui following a successful PUFF model run, or can be directly invoked from the command line.

6.1 PUFFVIEW

The puffview utility provides the capability to display, print, and generate .gifs and charts for ash data overlaid on a map. It provides numerous options for the display of the ash data, as well as for the selection of the underlying map characteristics. Its operation and options are described in this section.

Type "puffview" at the command line to run the puffview utility. If you are interested in viewing data from a particular ash file, you can specify one or more files on the command line. This has the added benefit of automatically centering the map on the region of interest. For example:

```
%> puffview "99.096.1000_ash.cdf 99.096.1100_ash.cdf"
```

A window will be displayed and the basemap loaded. Once the map has loaded, the user may select from a number of options.

Puffview can also be run with any of the options defined in puffview.args. The usage is

```
%> puffview [-option] [ashfile list]
```

6.1.1 Display Areas

The top part of the display contains a listbox with names of currently loaded ash files; an information box that reflects information about the ash file if one is selected; a legend that reflects the colors associated with ash particles at certain heights; a legend that reflects the icon associated with each pushpin type and whether the pushpin type is actively displayed; a button that causes all open ash files to be reloaded (redisplayed); a button that controls the animation of the ash dispersion (given multiple ash files); and a button to control the speed of the animation.

The bottom part of the display area contains the map and ash display. In the bottom right hand corner is a latitude/longitude display of the cursor position. To update this display, move the mouse cursor (cross) to the desired location and left-click.

Latitude is reported in positive decimal degrees North or South and longitude is reported in positive decimal degrees East or West.

6.1.2 Menu Options

6.1.2.1 File

6.1.2.1.a Open …

This option opens a file chooser dialog box that allows traversal to the directory of your choice and the selection of an ash file for opening. Each open ash file is listed in the "Ash Valid" file list in the top left-hand corner of the display. Note that data from the file are not automatically loaded when the file is opened. The data from one or more files may be loaded by double-clicking on the names in the list; selecting names in the list and choosing the Ash | Load menu item; or choosing the Ash | Select All and Ash | Load menu items. The list supports multiple selection via three methods:

- § click-and-drag : Click on the first file of interest, and while holding the mouse button down, drag to the last file of interest
- § shift-click : Click on the first file of interest and shift-click on the last file of interest to select the two files and all that appear between them
- § control-click : Click on the first file of the group and control-click on remaining files to add them to the selected group

The information shown in the Ash Valid list includes the date and time associated with the position of the ash particles, followed by the number of simulation hours elapsed at the time the ash snapshot was taken (and the file was written). For example:

> 06/11:00z (11hr) corresponds to a file containing ash locations for the 6th of the month at 1100z; this file contains the locations of ash 11 hours after start of eruption.

6.1.2.1.b Print …

The currently displayed map, ash distributions and pushpins can be printed via this option. Make sure that the desired ash file is highlighted (selected) in the ash list before choosing this option.

After selection of the option, a dialog box is displayed that allows the specification of a print queue for printing. The print queue entered should correspond to a printer with Adobe Postscript capability. The page orientation can be selected by clicking on the orientation button.

6.1.2.1.c Save …

All currently loaded ash distribution files can be saved to postscript or gif format via this option. The resulting postscript or gif files will contain map graphics overlaid with the specified ash distribution files and overlaid with all displayed pushpins, for either printing or display on a web page. Animated gif generation, which combines several ash distribution files into one animated gif, is also an option.

After selection of the option, a dialog box is displayed that lists all of the currently loaded ash distribution files. The set of files which are to be saved can then be selected from the list – either a single file can be selected by clicking, or a range of files can be selected by clicking the first one and dragging down to the last one. By default, no ash distribution files are selected.

The save format can be selected by clicking the save option menu button. If one ash file has been selected, it may be saved either as a .gif or as .ps file. If a range of ash files has been selected, animated gif may be chosen as well. For a range of files, a choice of gif or postscript will result in multiple output files, as shown on the 'file' text line, while animated gif will result in a single file.

If either gif or animated gif is selected, the gif size may be selected, which is the width of the gif in pixels. (If postscript output is selected, the width/height selection is ignored.) The gif's height in pixels will be calculated, based on the aspect ratio of the currently selected basemap (which can be changed via the Map Options menu selection on the main puffview File menu). The range of gif widths which can be selected is from 260 to 800 pixels. The maximum height is 725 pixels, and the map will be cropped at the bottom if the selected width would generate a height greater than 725 pixels for the current basemap. The 'portrait/landscape' selection is not meaningful for the gif output (it can be set only to portrait.)

The file name(s) for the save files may be changed from their defaults as well as the save directory. The user may specify either a leading ~ or a leading . for the directory name if a user-relative or relative path for outputs is desired; the GUI will translate this to an absolute path for display. (Note: paths containing the '../' construction are not supported.) The directory and output file name may also be selected via the 'browse' mechanism.

6.1.2.1.d 4x4Chart …

This option allows the printing of small map charts, corresponding to the VAFTAD-style output. The output is two pages of postscript output, with four rows and two columns of ash overlaid maps on each page, for a total of 16 maps on the 4x4 chart.

Each row of the chart is a plot of Puff predicted ash distributions at selected elevations ranges. The bottom row gives the combination ash plots over all included elevations.

Each column of the chart is a different time from the eruption, selected from the times available as a result of the 'save interval' selection of the Puff simulation run.

The default values for both elevation ranges and time of snapshot are the VAFTAD standard values, as follows:

- top row – elevation range 35,000 ft to 55,000 ft
- second row – elevation range 20,000 ft to 35,000 ft
- third row - elevation range surface to 20,000 ft
- bottom row - elevation range surface to 55,000 ft

- first column – 12 hours after eruption
- second column - 24 hours after eruption
- third column - 36 hours after eruption
- fourth column - 48 hours after eruption

Note: to be able to specify these times, your Puff simulation needs to extend past 48 hours and the save interval needs to be 12 hours or a divisor thereof.

Clicking this option on the main menu brings up a dialog box that allows the user to specify both elevation and ranges, with the defaults filled in. If the Puff simulation did not generate the files with the default times, the times of the first four saved ash files are selected as the defaults. Any four time periods that are available, as listed at the top of the dialog box, may be selected. You may also select any three elevation ranges. Ranges are distinct, and are specified by consecutive dialog boxes. The elevation ranges are specified on the dialog box in 100's of feet, to match the chart's annotation. Specify 550 for 55,000 ft.

The remaining fields of the dialog box allow the selection of an output directory and file, and function the same as the corresponding fields on the Save… dialog box. By default, the directory is the same one specified on the Save… dialog box, or is defaulted from the puffview arguments file contents at the time the program was built. The default name is the volcano name followed by the eruption time, with any non-alphanumeric characters in the volcano name being suppressed.

If the selected Map Options… aspect ratio is too wide or too narrow, the map will be shrunk or stretched to fit into a box size that will display on the output page. The software will warn about this condition; if you get this warning you may wish to go back to Map Options… and resize the map.

Note the discussion in the Map Options … section on the 'coastline' selection for decreasing the file size of the output.

6.1.2.1.e Map options …

This option brings up a dialog box permitting the user to select the following options:

1. Map projection – The user can click on the button underneath the "Projection" label to see the supported projections. Currently the choices are Mercator and Polar Stereo (North and South). The underlying map program (GMT) supports all major projections and additional ones could be added to the choices if desired. Note that North Polar Stereo is only usable for points in the northern hemisphere and South Polar Stereo is only usable for points in the southern hemisphere.

2. Coastline – GMT supports five levels of detail in the coastline data (crude, low, intermediate, high, full). The two highest resolution datasets are not loaded on the AFWA system. Those files are large and take proportionally longer to load. For most purposes, the "low" or "intermediate" resolution selections are satisfactory. If the higher resolution datasets are desired, they can be added upon request.

   When generating the 4x4 charts, it is best to set this detail level to 'crude', since the maps will be small and the difference between 'crude' and 'low' will not be apparent on the printout. This setting will result in a decrease in the output file size by a factor of 2. The output file size decrease is also true of the gif and animated gif, although if a larger .gif pixel size is selected you might notice the difference between 'crude' and 'low'.

3. Grid – The grid options determine the presence or absence of latitude/longitude grids on the map, and if present the degrees of spacing between adjacent lines.

4. Video – This allows "normal" or "reversed" coloring of the displayed map. This is a similar effect to viewing the negative of a photograph. In some cases, the "reversed" view might provide better contrast or a more desirable view.

5. Latitude and Longitude ranges – These may be specified by entering the boundaries in numeric fashion (directly or by scrolling to the desired values) or by defining an area of interest on the map depicted in the lower part of the dialog box. To define an area, move the mouse to the upper left corner of the area of interest, depress and hold down the left mouse button, drag to the lower right desired extent, and release the mouse button.

   Note that the map repeats geographical coverage, allowing longitude entries from 0 degrees East to 540 degrees East. This allows the user the flexibility to select an area of interest crossing the prime meridian without having the display of ash appear to move off the right side of the display and onto the left side.

6. Symbol size - This sets the size of the symbols used to represent the ash. The larger the number, the larger the size. The range is 0 to 10 in steps of 2. Selecting 0 will

display the ash data as single pixel points (i.e., no symbols – for other sizes a circle is used as the symbol).

7. Map size – Width of the map in inches. Valid range is 1 to 18, with a default of 12. If the aspect ratio of the area being mapped is narrower than 1:1, the map width might be dynamically reduced to limit the vertical size of the map, which is limited to 18 inches like the horizontal extent. For example, if you select a map width of 12 inches, and select a Mercator projection that is 20 degrees wide in longitude and 60 degrees high in latitude, the displayed width will be reduced to the point where the vertical height of the resulting display is <= 18 inches. This change in width will be reflected in the width option in the dialog box after the map is drawn.

After specification of the desired parameters, the user can click on the "Save & Map" button to save the choices and regenerate the basemap or click Cancel to exit the dialog without saving or action.

6.1.2.1.f Exit

Selection of this option closes the puffview window and exits the program. If the program was invoked automatically following a model run, the parent puffgui process is terminated as well.

6.1.2.2 Ash

6.1.2.2.a Select All

This menu item selects all the ash files listed in the ash list box in the puffview window. Note that the file list box must have input focus for this to work. The easiest way to give the box focus is to single left click on one of the ash files, then choose Ash|Select All. Multiple selection capability is also available using the mouse (i.e., shift-click and control-click conventions are supported).

6.1.2.2.b Load

This loads the selected ash file and displays the corresponding distribution on the basemap. The term "load" in this case means that ash data sets are created and are available for overlay on the map. Once the file has been loaded, a "+" is displayed to the right of the file name. If multiple files are selected for loading, each is loaded in turn. At any given time only one ash data set will be depicted on the map, and if multiple files are selected the end state will have the last data set in the list depicted. The Load function can be accessed from the keyboard via the Control-L key combination.

6.1.2.2.c Clear

The “Clear” menu item causes the ash data corresponding to the selected ash file to be removed from the basemap display. The ash file continues to be listed in the ash file list box. The Clear function can be accessed from the keyboard via the Control-C key combination.

6.1.2.2.d Delete

The “Delete” menu item causes the selected ash file to be removed from the list box and its ash display removed from the basemap (if it had been displayed). This does NOT actually delete the ash file from the directory. The Delete function can be accessed from the keyboard via the Control-D key combination.

6.1.2.3 Tools

6.1.2.3.a Pushpins Selection

The "Pushpins Selection" menu item brings up a dialog box which lists all the location identifiers (pushpins) that can be displayed on the current map. The pushpins with a check mark are allowed to be displayed and will be displayed if or when their corresponding pushpin type in puffview's pushpin legend is also selected. Pushpins that are not checked are not displayed. This dialog box permits the user to specify which pushpins he wants displayed on the map and which pushpins he does not want displayed. All pushpins are placed in the selected mode when puffview is started. The current selections will take effect when the user clicks on "Accept Selections". When "Cancel" is clicked the window is exited with no changes.

Note: To permanently delete pushpins or to add new pushpins, the user may edit the pushpins.txt file. Its pathname is found in puffgui.args labeled "pinPath". The first few lines of the file are comments which aid in editing. They are:

```
# List of PushPins
# PushPin names must have no spaces, can include _ or numbers.
# Duplicate pushpin names will have a number affixed to make them unique.
# Latitudes/Longitudes may be decimal (41.70) or degrees/minutes (41 42).
# To temporarily delete a pushpin, put a # sign (comment) in column one.
# This file is read in and in force only when puffview is started up.
#
#       Countries
AFGHANISTAN     :country        :33 :N          :68.3 :E
```

6.1.2.4 Help

6.1.2.4.a Balloon Help

Balloon help enables short descriptive text notes that display when the mouse is positioned near a particular displayed feature. This capability is normally enabled. It can be toggled between enabled and disabled by clicking on this menu item.

6.1.2.4.b on Version

Clicking on this menu item causes an informational dialog box to display that contains program author and version information.

6.1.3 Ash List

A list of “opened” ash files is given in the top left-hand corner of the display under the title "Ash Valid". Once one or more ash files have been opened and appear in this list, they can be selected and loaded.

6.1.4 Volcano Information Summary

To the right of the ash file list is the volcano information summary. This will display the volcano name and location associated with the selected ash file. It also displays the reference time for the file (i.e., the time of the first data).

6.1.5 Loop Option

Below the volcano information is a button nominally labeled “Loop”. If more than one ash file has been loaded (signified by a “+” to the right of the name), the apparent motion of the ash can be simulated by clicking on the Loop button. It will display each ash data set in sequence to animate the movement of the ash. Once the loop function has been selected, this button’s label changes to “Stop.” Clicking Stop will cause the animation to cease at the end of the current cycle (i.e., with the last ash file in the sequence).

There is a slide control below the Loop button that can be used to control the animation rate. Moving it to the right increases the rate.

6.1.6 Ash Level Depiction

The ash level depiction bar functions as a legend and as a control. As a legend, it correlates ash colors with ash altitude. As a control, the user has the options listed following this paragraph. Note that the display is cleared upon the first change to the legend to reflect the fact that the ash data display no longer correlates with the information in the legend. The ash data are not automatically redrawn after a change, thus permitting the user to make all desired adjustments without waiting for intervening

redraws. All open ash files can be re-displayed by clicking on the “Reload All Ash” button located below the legend. Alternatively, any of the previously described methods for loading one or more ash files can be used.

1. The number of distinct levels represented can be changed by clicking the upward (increasing) or downward (decreasing) pointing arrows to the left of the display. The minimum number is 1 and the maximum number is 16.

2. The color used to represent a given level can be changed by right-clicking on the color and selecting a different choice from the popup list. There are 16 possible colors.

3. The color scheme used to display the ash can be changed by selecting one of the items in the drop-down list below the color bar. The list is shown as a button labeled with the default color scheme, “*Rainbow*”. There are 7 possible color schemes.

4. The minimum ash altitude displayed can be adjusted by dragging the small open rectangle on the left side of the color bar to the position desired (drag by positioning the mouse cursor over the rectangle, pressing and holding the left mouse button, moving the mouse to the right, releasing the mouse button). Note that the open rectangle becomes a solid black rectangle when the mouse cursor is over it.

5. The maximum ash altitude displayed can be set by dragging the small open rectangle on the right side of the color bar to the position desired.

6.1.7 Symbol Size

Like the option by the same name on the Map Options dialog box, this controls the size of the symbols representing the ash. Unlike the ash level control just described, the display redraws immediately when this value is changed. The range is 0 to 10 in steps of 2, with 0 resulting in single pixel display (no circle symbol).

6.1.8 Pushpins

A list of pushpin types are given in the top right-hand corner of the display under the title "Pushpins". It shows the icon associated with each pushpin type. The corresponding button list to their right allows the user to select the types of pushpins he wants displayed on the map. Pushpins will be displayed on the map with their icon at the location of the object and the pushpin name to the left of it. Types like "country" or "state" will have only the pushpin name displayed. Upon selecting a pushpin type, the ash cloud is refreshed on the map and the pushpins of that type are displayed (unless they had been individually disabled by the "Pushpins Selection" menu).

Note: To permanently add or delete pushpin types, the user may edit the pushpins.cfg file where they are defined. Its pathname is found in puffgui.args labeled " pushpinCfg ". The first few lines of the file are comments which aid in editing. They are:

```
# List of PushPin types
# There is a practical limit of seven pushpin types.
# If more than 7, you get scrolling and the list only shows 7.
# Names must be one word, can have _ or numbers.
# Possible symbols: none circle cross diamond plus square triangle.
# Possible colors: black blue brown gray green orange pink red white yellow
# The printout of Puff maps only recognizes the above colors, default is black.
# In unix type "showrgb" for more screen color possibilities.
# When you delete a pushpin type, you must also delete any pushpins of that
# type in the pushpins.txt file
#
AFB             :plus           :blue           :black  :12     :deselect
```

7 AFWA2PUFF Operation

Windfield data stored in GRIB files needs to be converted to netCDF files of appropriate format for PUFF to work. The "afwa2puff" utility can convert AVN, NOGAPS, MM5, and Datacube GRIB files to puff input files.

Afwa2puff can be run from the command line or can be invoked via the File | GRIB convert … menu item on the puffgui dialog box. If invoked from the command line, certain options need to be specified, preferably in a text input file. Assuming the name of the options file is afwa2puff.input, the following command will invoke the utility:

```
%> afwa2puff –argFile "afwa2puff.input"
```

All of the options listed in Table 3 Required Option Specification for afwa2puff *for which the default values are not desired* must be specified correctly in the options input file. Defaults are specified in the following text file: <your puff installation path>/src/puffsrc/puff.args. See Section 9 (Maintenance Notes) for details.

Table 3 Required Option Specification for afwa2puff

Option	Description
model	Wind model for source (avn, nogaps, mm5, avn-datacube, merge-datacube)
avnPath[1]	Pathname to the AVN model GRIB file directory
nogapsPath[1]	Pathname to the NOGAPS model GRIB file directory
mm5Path[1]	Pathname to the MM5 model GRIB file directory
avnDatacubePath[1]	Pathname to the AVN-based Datacube GRIB file directory
mergeDatacubePath[1]	Pathname to the AVN and merged MM5-based Datacube GRIB file directory
path[1]	Pathname to directory where resultant windfield netCDF files will be written.
volcLat	Latitude (decimal degrees N) of the volcano of interest (the grid of data will be centered around this)
volcLon	Longitude (decimal degrees E) of the volcano of interest
lonDeltaMax[1,2]	Extent (from the volcano location) in the positive direction of East longitude for which wind data will be converted (positive number of degrees)
lon DeltaMin[1,2]	Extent (from the volcano location) in the negative direction of East longitude for which wind data will be converted (NEGATIVE number of degrees)
latDeltaMax[1,2]	Extent (from the volcano location) in the positive direction of North latitude for which wind data will be converted (positive number of degrees)

Table 3 Required Option Specification for afwa2puff (cont'd)

Option	Description
latDeltaMin[1,2]	Extent (from the volcano location) in the negative direction of North latitude for which wind data will be converted (NEGATIVE number of degrees)
theater[3]	MM5 theater of interest (integer; e.g., 3)
nestId[3]	MM5 nest of interest (single char; e.g. "c")
minConvertHours	Minimum number of hours of forecasts to convert (3 – 72 in multiples of 3)
desiredConvertHours	Desired number of hours of forecasts to convert (3 – 72 in multiples of 3)
eruptDate	Date/time string of volcano eruption of interest

Notes:

(1) These values need to be specified in the file ONLY if you want to use a non-default value. Additionally, even in that case the only GRIB file path that must be specified is the one for the model type you're using (e.g., nogapsPath when using the NOGAPS model)

(2) Only for lat/lon based grids (e.g., NOGAPS/AVN/Datacube)

(3) Only for XY based grids (e.g., MM5)

For example, following is a sample input file:

```
\model "nogaps"
\path "./puffdata/partial"
\volcLon "250.55"
\volcLat "-27.12"
\lonDeltaMax "50"
\lonDeltaMin "-50"
\latDeltaMax "20"
\latDeltaMin "-20"
\minConvertHours "12"
\desiredConvertHours "24"
\eruptDate "1999 04 06 00:00"
```

Because the files associated with a particular forecast cycle are produced by the model processes over a period of time (can be several hours) and appear in the parent directory as they are produced, the afwa2puff program must be able to recognize when a forecast cycle set is incomplete and determine how best to satisfy the user's request. The algorithm it uses works as follows:

1. The user specifies the volcano eruption time.
2. The user specifies minimum and desired forecast time coverages. The number of forecast hours represents the number of hours *beginning with the volcano*

eruption time for which user is interested in modeling the volcanic ash dispersion.

3. Afwa2puff determines the latest forecast cycle available (as determined by the presence of the 00 base file (for "a" nest in MM5 case) or .anl file (NOGAPS case) whose date/time is equal to, or earlier than, the eruption time.
4. (Non-MM5 case) Based on this forecast cycle, afwa2puff generates a list of the associated forecast files. It iterates through those files, eliminating from consideration any that don't have the same cycle time as the base file or are not readable for any reason (e.g., permissions problem), and inspecting the forecast hours value. It continues to process the list until it reaches a file whose forecast time is equal to or greater than the desired number of forecast hours, or until it exhausts the list.

   The desired forecast time coverage starts at the volcano eruption time and runs for "desired convert hours" hours. Consequently, the system may end up processing more than the desired convert hours if the volcano eruption occurs just prior to a new forecast cycle. For example, suppose the eruption time is 1100z, and the user desires 12 hours of forecast coverage. Assuming two forecast cycles a day, the program will select the 0000z base cycle and process 24 hours worth of data (0000z to 2300z). Note that the program will detect as many base cycles as exist for the model type, regardless of the cycle times.
5. If at least the minimum number of hours are available, it will use this list of files. Otherwise, it looks for the next earlier base cycle and repeats the process.
6. For the MM5 case, the program selects base cycles based on the "a" nest, regardless of user request. That's because the subnests frequently start some number of hours after the base cycle. Following selection of the base cycle files, the program searches for files from the user-specified nest. With each file set it must consider whether the effective start time of the data (base cycle time + forecast time) falls at or before the eruption. If not, it eliminates this base cycle from consideration and searches for the next earlier one.
7. If there are no forecast cycles that meet the requirements, afwa2puff issues an error message so stating and terminates.

When run from the command line, the utility will print out estimates of percentage complete to the screen. The final step in the processing is the writing of the two windfield files (U and V) to the directory specified by the path option. The filenames are constructed automatically based on the eruption date provided.

The time required to produce PUFF input files depends primarily on the number of hours of forecasts converted (minConvertHours and desiredConvertHours) and number of pressure levels and secondarily on the size of the grid surrounding the volcano. On a fast platform, such as a multiprocessor Sun Ultrasparc with 768 MBytes

of RAM, it takes less than a minute to process 48 hours of AVN forecasts for the default grid size of +/- 15 degrees in latitude and +/- 30 degrees in longitude. There is little time penalty associated with expanding the grid size say to +/- 30 and +/- 60 degrees respectively. However, the resultant file sizes are significantly larger.

The dominant time driver is the data conversion to create the input files. The model itself is very fast (< 30 seconds) for simulations modeling the nominal number of ash particles.

8 ASHDUMP Operation

Once ash files have been created, their contents may be viewed overlaid on a map using the puffview utility. However, it is sometimes useful to be able to examine ash files from the command line, especially since many files can be created in a single run and the file naming convention conveys only date information. The "ashdump" utility is designed to provide the user with the ability to examine descriptive information in the file as well as to dump the actual contents if necessary.

Ashdump is run from the command line and uses the following syntax:

```
%> ashdump <ash file name> [options]
```

The header option lists the major variable in the file (the ash list), the dimensions along which those data are stored (time, level, lon, lat), and a series of descriptive data. Specifying additional options (e.g., -lat) results in the data for that variable being displayed. Normally the command line usage is to simply request the header information. The header will tell you enough about the valid time, applicable volcano, geographic range of coverage, etc., to answer most questions. However, if you would like to do some additional processing on the data from one or more files, this utility provides an easy way to dump those data without having to understand the netCDF file format.

The options are given in Table 4 Ashdump Utility Options. You can display the options on screen by entering:

```
%> ashdump –h
```

Note that for the options in Table 4 Ashdump Utility Options, with the exception of <infile>, all items must be immediately preceded by a dash ('-').

Table 4 Ashdump Utility Options

Option	Description	Default
<infile>	Input ash file	
lon	Print lon field using ashdump	false
lat	Print lat field using ashdump	false
z	Print height field using ashdump	false
sz	Print size field using ashdump	false
age	Print age field using ashdump	false
hdr	Print ash header information	false
stats	Print basic ash stats with ashdump	false
active	Print only active ash with ashdump	false
range	Lon/Lat range for read or mapping	"-180/-120/60/75"
height	Height range filter for mapping	"0/20000"

Table 4 Ashdump Utility Options (cont'd)

Option	Description	Default
feet	Use feet instead of default meters for height values	false
size	Size range filter	"0/1.e30"
shiftWest	Shift lon values from -180:180 to 0:360	true
shoparams	Show puff parameters used	false
width	Set width of output in ashdump	14
precision	Set precision of output in ashdump	0
help	Print this summary	false

9 Maintenance Notes

9.1 Default Values

Default values are maintained in the following text file:

<your puff installation path>/src/puffsrc/puff.args

The format of the file must be carefully adhered to. The contents of this file are incorporated in the executables created during the build process via macro processing during compilation. The general format is:

ARG(<parm name>,<parm type>, <default value>, <descriptive string>)

The parm name is the parameter name and must not contain spaces. If a multiple word parameter is desired, the convention is to run the words together, but capitalize the first letter of all words after the first.

The type can be one of double, long, string, or name. The default value is given in quotes for string types.

To change a default value, edit the value in the puff.args file and completely rebuild the application. To rebuild the application, change directory to:

<your puff installation path>/src

and type:

make clean
make all

This is necessary because, as noted, the defaults are embedded in the executable via a macro processing step during compilation.

9.2 GRIB Filename Conventions

For each of the possible GRIB model sources, there is a skeletal filename description in the puff.args file. The convention followed is to use a question mark (?) to represent all characters in the GRIB filename that are irrelevant to the conversion and using special single-character codes to indicate the location in the names of the cycle hours and minutes and forecast hours and minutes. The codes are as follows (case matters):

c	cycle hours
d	cycle minutes

f	forecast hours
g	forecast minutes
t	theater
n	nest

Cycle hours and forecast hours are required in all cases. Theater and nest entries are required for the MM5 files. Cycle minutes and forecast minutes are optional (from afwa2puff's perspective). If the filename uses three digits for forecast hours, use three 'f' characters in the skeletal filename. The parsing algorithm expects minutes to follow hours, but not necessarily directly. Other than that, there is no constraint on the location of the key values. Following are some current examples:

NOGAPS:

Base filename: nogaps.T00Z.000
Skeletal filename: ??????.?cc?.fff

Note that in this case the skeletal filename contains periods at the same positions as those in the real filename. This is not required; they could be replaced with question marks. The presence of the periods provides more protection against inadvertent access of unrelated files in the directory.

AVN:

Base filename: gblav.T00Z.PGrbF00
Skeletal filename: ?????.?cc?.?????ff

MM5:

Base filename: us057g1010t03a060000000
Skeletal filename: ???????????ttnccddfffgg

If any of the GRIB file name formats change in the future, simply revise the skeletal description in the puff.args file and rebuild the executable.

10 Quick Reference Guide

General Process

(a) Start puffgui -> `%> puffgui`

(b) Select volcano

(c) Convert GRIB data to PUFF input data -> `File|GRIB convert` …

(d) Specify eruption parameters

(e) Run PUFF -> `File|Run`

(f) Adjust color-to-ash altitude mapping if desired (then reload all ash files)

(g) Exit -> `File|Exit`

<or>

Re-run PUFF with different eruption parameters by returning to the puffgui dialog window (still open), changing desired parameters, and selecting `File|Run` again.

11 Troubleshooting and Limitations

11.1 Limitations

11.1.1 Lat/Lon Coverage

Results for near-polar volcanos or ash migration are not handled in this version of PUFF. In particular, it should not be used for latitudes greater than 85 degrees North or less than –85 degrees North. This is not a model limitation (the model handles polar locations); it is related to the algorithms used for some of the coordinate conversions.

11.1.2 Lat/Lon Range of Windfile Production

The afwa2puff dialog limits selection of relative longitude range around the volcano to +/-30 <= range <= +/-180 degrees. The latitude relative range limits are +/- 15 <= range <= +/- 90.

11.2 Troubleshooting

11.2.1 Run-to-run variation

If I run the PUFF program using the same input windfile and identical run parameters for several runs, I get slightly different results.

That's because many of the processes used in modeling the ash dispersion include random elements. For example, ash size, initial vertical and horizontal dispersions, and diffusion all include random values in their computations. Runs can be made repeatable by specifying the same random generator seed value over multiple runs. This is done by setting the "seed" option to 0. (e.g., puffgui –seed 0, puff –seed 0, or in the input file as \seed "0")

11.2.2 Ash out of bounds

I get "Ash Out of Bounds" warning messages when I run PUFF and I don't get as many ash files produced as I expected.

The program tests each of the ash particles for each integration step to determine whether they have moved outside the available wind data. If this occurs, that integration step is completed, a warning is issued, and if any data have been produced since the last ash file was saved, a final ash file is produced. To address this situation, create an input windfile covering a wider range around the volcano. This can be done from the afwa2puff dialog (select File|GRIB convert … from the puffgui dialog) by entering larger numbers in the relative latitude and/or longitude range to convert.

11.2.3 No available wind data for model chosen

I know that I have created input wind files for PUFF but none of the associated cycles appear in the Cycle combo box in puffgui.

The cycles listed are determined by searching the directory specified by the "path" option for files with filenames that match a pattern associated with the model type. If you don't see files that should be visible, it's probably because the path is set incorrectly. Select File|Options… from the puffgui dialog to get the general options dialog box. Then select "path" from the options combo box and enter the correct path. This path can be fully qualified or relative. Click on the Save button. The program will scan the new directory and add entries to the Cycles list if any files are present.

11.2.4 Eruption date widget takes too long to change a date

I need to look at data from several months ago, but the puffgui eruption date display always comes up with the current date. How do I specify a date directly?

Eruption date is a general option (eruptDate) that can be specified on the command line when you launch puffgui. The date specification **must** be in the following format and enclosed by double quotes if presented on the command line:

YYYY MM DD HH:MM

For example:

```
%> puffgui –eruptDate "1999 04 06 00:00"
```

This will start the dialog box preset to the desired date.

11.2.5 PUFFVIEW doesn't change map display to focus on a new volcano

I did a PUFF run with a particular volcano, and after viewing the results with puffview, decided to do a run with a different volcano. Without exiting puffview, I selected a new volcano in puffgui and ran the simulation. New ash files were loaded into puffview but the display didn't change. Why not?

When puffgui completes running puff and invokes puffview the first time, puffview looks at the volcano location (contained in the ash files) and configures the map accordingly. If you do another run with a volcano in a different location, and puffview is already running, it **won't** automatically change the display. That's because it takes a long time to reload the basemap and it assumes that most of the time you would be re-running the same volcano with different parameters. However, it does pre-load the new location into the Map Options dialog box. So to go directly to the new location, select File|Map Options and click on the "Save & Map" button in the dialog. All of the settings will be preset, and this will cause the new basemap to load.

11.2.6 Map Projection Changes from Mercator to Polar Stereo

Sometimes the initial map projection uses the Mercator projection and sometimes it uses the Polar Stereo by default. What's the rule?

The program defaults to Mercator if the latitude of the volcano is in the range 60 N to –60 N. If it's north of 60 N, a Northern Polar Stereo projection is used, and if it's south of -60 N then a Southern Polar Stereo projection is used. The user has the option of changing the selection and reloading the basemap by using the Map Options dialog box in puffview.

11.2.7 GMT Error

When I try to run Puff or open the Cloud Editor, I get the message "Error: GMT: Could not create file .gmtdefaults".

GMT are the mapping tools that puffgui and puffview use to display its maps. If the directory out of which you are running the GUI is not writeable, you will get this error message when trying to display a map. Run out of a directory for which you have write permissions.

11.2.8 Multiple Eruptions with Cloud Files

When would I use "Run New Eruption with Existing Cloud"? If I want to run a new eruption where there is already an existing ash cloud, can't I just run a simulation using "Run with Existing Cloud", then run a multiple eruption using "Run Multiple Eruption", using an ash file from the first simulation?

Yes, you can, but be aware that two scenarios aren't exactly the same. The second scenario requires two runs of puff – the first run generates an ash file to use in the second run. As a result, the initial ash cloud has already begun to disperse by the time it is used in the second run (at the time of the new eruption). If you have remote sensing data that describes the first ash cloud at the time of the second eruption, you will achieve better results with "Run New Eruption with Existing Cloud". On the other hand, if your remote sensing data describing the first cloud is old by the time the second eruption occurs, you may wish to use the second scenario.

11.2.9 Wind Range Error on GRIB Convert

When I try to run the GRIB to PUFF windfield data conversion, I get an error message stating "File Creation Failed: Error: afwa2puff: Wind range error – first wind data is at YYYY MM DD HH:MM+Hhr". What does this mean?

When running the GRIB wind file conversion, the afwa2puff application searches your wind file directory path to see whether there is coverage for your eruption date. If it does

not find valid data for that date, it cannot run the GRIB conversion. You will need to either select an eruption date for which you have valid data, or change your GRIB file path to point to a valid directory containing data for your eruption date. This can be done either by changing the default path in your .args files (see section 9.1) or by calling puffgui with the appropriate command-line argument (see section 4.2.1).

12 APPENDIXES

APPENDIX A – Acronyms and Abbreviations

AACGM	Attitude Adjusted Corrected Geomagnetic
ACE	Advanced Composition Explorer
AFCCC	Air Force Combat Climatology Center
AFOSR	Air Force Office of Scientific Research
AFRL	Air Force Research Laboratory
AFSCN	Air Force Satellite Control Network
AFSPACECOM	Air Force Space Command
AFSWC	Air Force Space Weather Center
AFWA	Air Force Weather Agency
AFWIN	Air Force Weather Information Network
AF/XOW	Air Force Director of Weather
APL	Applied Physics Laboratory of Johns Hopkins University
ASCII	American Standard Code for Information Interchange
ASPAM	Atmospheric Slant Path Analysis Model
AVHRR	Advanced Very High Resolution Radiometer
AVN	Aviation Model
AVO	Alaska Volcano Observatory
BATS	Biosphere-Atmosphere Transfer Scheme
CLASS	Canadian Land Surface Scheme
CME	Coronal Mass Ejections
COE	Common Operating Environment
DII	Defense Information Infrastructure
DMSP	Defense Meteorological Satellite Program
Dst	Disturbance, storm
ECMWF	European Center for Medium-Range Weather Forecasts
EIT	Extreme Ultraviolet Imaging Telescope
EVA	Extravehicular Activities
FAC	Field Aligned Currents
FNMOC	Fleet Numerical Meteorology and Oceanography Center
FSL	Forecast Systems Laboratory
FTP	File Transfer Protocol
GDS	Grid Description Section
GI	Geophysical Institute
GIC	Ground Induced Currents
GIF	Graphic Interchange Format
GIT	Georgia Institute of Technology
GMT	Generic Mapping Tools
GOLD	Geophysical On-Line Data
GOES	Geostationary Operational Environment Satellite
GRIB	Gridded Binary
GSE	Geocentric Solar-Ecliptic
GSFC	Goddard Space Flight Center

GUI	Graphical User Interface
HLBL	High Latitude Boundary Layer
IDL	Interactive Data Language
IMF	Interplanetary Magnetic Field
ISS	International Space Station
JHU	Johns Hopkins University
JHU/APL	Johns Hopkins University/Applied Physics Laboratory
Kp	Planetary Index of Geomagnetic Activity
LAN	Local Area Network
LAPS	Local Analysis and Prediction System
LASCO	Large Angle Spectroscope Coronagraph
LEO	Low-attitude Earth Orbit
LSM	Land Surface Model
MATCH	Model of Atmospheric Transport and Chemistry
MeV	Million Electron Volts
MM5	Fifth Generation Mesoscale Model
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
netCDF	Network Common Data Form
NGDC	National Geophysical Data Center
NGM	Nested Grid Forecast Model
NOAA	National Oceanic and Atmospheric Administration
NOGAPS	Navy Operational Global Atmospheric Prediction System
NRL	Naval Research Laboratory
NWP	Numerical Weather Prediction
NWS	National Weather Service
OWS	Operational Weather Squadron
PACE	Polar Anglo-American Conjugate Experiment
PBL	Planetary Boundary Layer
PCA	Polar Cap Absorption
PDS	Product Definition Section
PFRR	Poker Flat Research Range
PNG	Portable Network Graphics
PUFF	From Puff the Magic (ash spewing) Dragon
RBE	Radiation Belt Environment
SAA	South Atlantic Anomaly
SABER	Sounding of the Atmosphere using Broadband Emission Radiometry
SD	Space Department of the Applied Physics Laboratory
SDP	Software Development Plan
SEC	Space Environment Center
SEE	Solar EUV Experiment
SEON	Solar Electro-optical Observing Network
SEP	Solar Energetic Particles
SFOC	Space flight Operations Center

SOHO	Solar and Heliospheric Observatory
SPE	Solar Particle Event
STP	Solar Terrestrial Physics
SWOC	Space Weather Operations Center (Offutt)
SWXS	Space Weather Squadron
SXI	Soft X-ray Imager
Tcl	Tool Command Language
Tk	Toolkit
Tix	Tk Interface Extension
UAF	University of Alaska, Fairbanks
UCAR	University Corporation for Atmospheric Research
UCB	University of Colorado, Boulder
UPOS	University Partnering for Operational Support
UTC	Coordinated Universal Time
WDC	World Data Center
WF	Weather Flight
WMO	World Meteorological Organization
XDR	External Data Representation