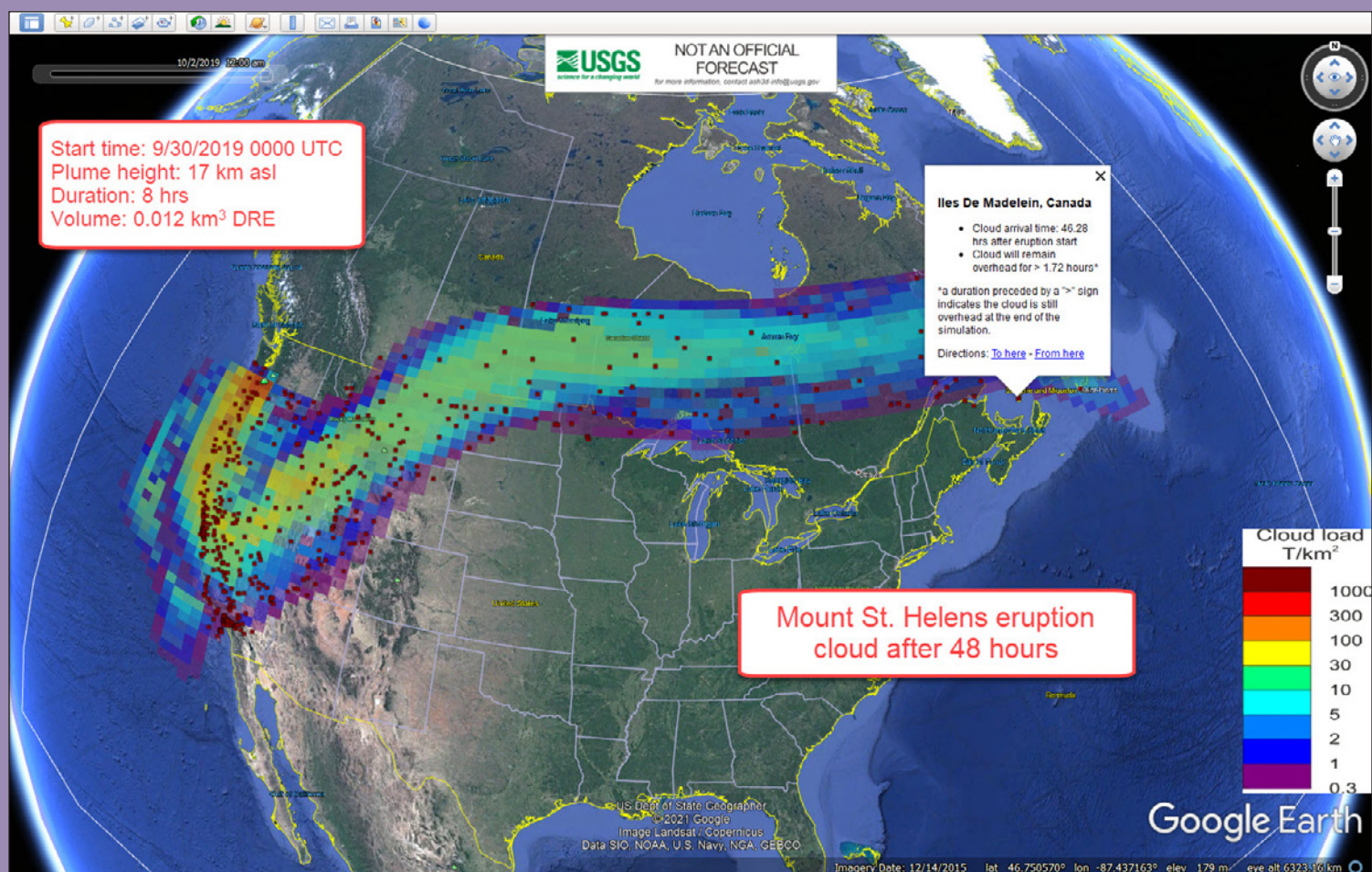


# User's Guide and Reference to the Web Interface of Ash3d— A Three-Dimensional Model for Atmospheric Tephra Transport and Deposition



Open-File Report 2013–1122  
Version 2.0, April 2021

**Cover.** Screenshot of the Ash3d simulation of a Mount St. Helens eruption with approximately the same plume height, duration, and eruptive volume as the May 18, 1980 eruption, but simulated with different wind conditions. This screenshot shows the mass load in the eruptive cloud 48 hours after the eruption start.

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By Larry Mastin, Michael J. Randall, Hans F. Schwaiger, and Roger P. Denlinger

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Version 2.0, April 2021

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U.S. Geological Survey**

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## Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
Length		
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
mile, nautical (nmi)	1.852	kilometer (km)
yard (yd)	0.9144	meter (m)
Flow rate		
foot per second (ft/s)	0.3048	meter per second (m/s)
Pressure		
atmosphere, standard (atm)	101.3	kilopascal (kPa)
bar	100	kilopascal (kPa)
inch of mercury at 60 °F (in Hg)	3.377	kilopascal (kPa)
pound-force per square inch (lbf/in <sup>2</sup> )	6.895	kilopascal (kPa)
pound per square foot (lb/ft <sup>2</sup> )	0.04788	kilopascal (kPa)
pound per square inch (lb/in <sup>2</sup> )	6.895	kilopascal (kPa)
Density		
pound per cubic foot (lb/ft <sup>3</sup> )	16.02	kilogram per cubic meter (kg/m <sup>3</sup> )

## Abbreviations

DRE	dense-rock equivalent
GFS	Global Forecast System
NOAA	National Oceanic and Atmospheric Administration
UTC	universal time, coordinated
VAAC	Volcanic Ash Advisory Centers





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By Larry G. Mastin, Michael J. Randall, Hans F. Schwaiger, and Roger P. Denlinger

## Abstract

Ash3d is a three-dimensional Eulerian atmospheric model for tephra transport, dispersal, and deposition to study and forecast hazards of volcanic ash clouds and tephra fall. In this report, we explain how to set up simulations using a web interface, and how to view and interpret model output. We also summarize the architecture of the model and some of its properties.

## Introduction

On January 15, 1989, the eruption of Mount Redoubt in Alaska's Cook Inlet sent an ash cloud toward the northeast. During that eruption, KLM flight 867 carrying 245 passengers and crew headed straight into the ash cloud, then attempted to climb out into clear air, when all four engines failed. The jet dropped by more than 14,000 feet (4,200 meters) before one engine was successfully restarted and the plane landed in Anchorage. Ash damage required that all engines be replaced, at a cost of about \$80 million (Witkin, 1989; Przedpelski and Casadevall, 1994).

The 1989 Redoubt event is only one of dozens of airborne encounters with ash that have damaged aircraft or led to flight disruptions that cost millions of dollars every year (Christmann and others, 2017). Atmospheric dispersal of volcanic ash is the most widespread volcanic hazard and the hazard with the greatest potential for economic disruption. The economic effects of ash distribution were demonstrated during the 2010 eruption of Eyjafjallajökull volcano in Iceland, when flight cancellations and delays throughout Europe caused billions of dollars in economic loss to airlines and travelers (Harris and others, 2012). This event also demonstrated that potential volcanic hazards are not limited to areas near the volcanoes. For example, flight cancellations and delays during the 2011 eruption of Puyahue/Cordon Caulle in Chile extended halfway around the world to Australia and New Zealand (Elissondo and others, 2016).

The most effective way to reduce risk from dispersed volcanic ash is by forecasting where it will go and what areas it will affect. Modern numerical weather prediction (NWP) models now enable us to routinely forecast ash movement in a three-dimensional (3D), time-changing wind field. Modern

computer power gives us the ability to run forecast models of ash movement within minutes of an eruption.

In this report, we describe how to use our model, Ash3d, to calculate tephra transport. Model results have been compared with observations from several eruptions. Ash3d provides a variety of output that can be used in research and operational applications. A companion paper (Schwaiger and others, 2012) describes the model physics. This paper describes the model's setup and use through a web interface. Ash3d is still in development, hence its capabilities and documentation are likely to be revised in coming years.

## Model Overview

Ash3d models ash transport by dividing the atmosphere into a 3D grid of cells (fig. 1A) and calculating the flow of mass through cell walls. At the beginning of a simulated eruption, tephra is injected at a constant rate into the column of cells above the volcano (fig. 1B). Using a 3D time-dependent wind field, Ash3d calculates downwind advection, diffusion, and settling of ash at a series of time steps, until ash is deposited or flows out of the model domain. Individual ash particles fall at a rate determined by their settling velocity in air, and deposit when they reach the ground surface.

## Initial Conditions

Ash3d does not calculate the dynamics of a rising plume. Instead, it injects tephra into a column of cells above the volcano (fig. 1B), and distributes mass vertically using the Suzuki equation (fig. 1B) (Suzuki, 1983; Carey, 1996),

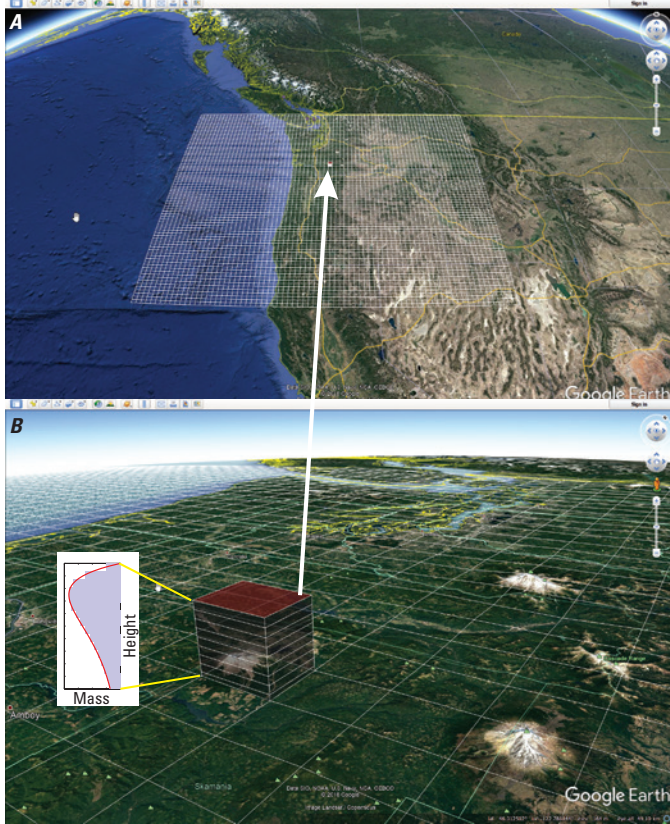
$$\frac{dQ_m}{dz} = \frac{(1 - z/H)e^{k(z/H-1)}}{H[1 - (1+k)^{-k}]} \quad (1)$$

where

- |       |  |
|-------|--|
| $Q_m$ | is the total mass of erupted material in each time step at a given particle size;        |
| $H$   | is the total plume height;   |
| $Z$   | is a given elevation in the plume; and   |
| $k$   | (the shape factor) is an adjustable constant that controls ash distribution with height. |

For web simulations we use  $k=4$ , which gives the distribution illustrated in fig. 1B.

During an eruption, Ash3d injects tephra into these cells at a specified rate. The grain-size distribution inserted into each cell in the column is the same at each elevation and for each eruptive pulse.



**Figure 1.** Screenshot of model grids illustrated in Google Earth. A, Latitude-longitude grid over the U.S. Pacific Northwest. B, Close-up of cells over Mount St. Helens, showing a vertical distribution of ash specified by equation (1), using a shape factor ( $k$ ) of 4.

### Transport

Ash3d solves for the conservation of mass in each cell by tracking the mass concentration  $q$  with time  $t$ ,

$$\text{Advection-Diffusion, } \frac{\partial q}{\partial t} + \nabla \cdot [(u + v_s)q] - \nabla \cdot (K \nabla q) = Q \quad (2)$$

where

- $u$  is the 3D wind vector;
- $v_s$  is the settling velocity;
- $K$  is the diffusivity; and
- $Q$  is a source term, which is non-zero only in the column of nodes above the volcano.

By default, Ash3d calculates the settling velocity of each particle size using equations of Wilson and Huang (1979)

for ellipsoidal particles, using a shape factor  $F = 0.65$  ( $F \equiv (b+c)/2a$ , where  $a$ ,  $b$ , and  $c$  are the semi-major, intermediate, and semi-minor axes of the ellipsoid). When simulating deposits, fine ash is represented as spherical aggregates, having a median size (0.1895 mm) and density (600 kg/m<sup>3</sup>) that optimizes the fit between Ash3d simulations and mapped deposits (Mastin and others, 2016).

The advection term of equation 2 (the second term on the left-hand side [LHS]) is calculated explicitly using the Donor Cell Upwind method of solution (see Schwaiger and others, 2012, for details). The diffusion term (third LHS term) is calculated implicitly at the end of each time step. The diffusivity is set to  $K = 0$ , for simulations using the web interface to maximize speed.

### Numerical Wind Fields

For simulations under current and forecast conditions, the Ash3d web version uses meteorology from the NOAA Global Forecast System (GFS) 0.5 degree model (National Centers for Atmospheric Prediction, 2021). For simulations that have eruption start dates two weeks or more before the run date, simulations use the NCEP/NCAR Reanalysis 1 2.5-degree model (Kalnay and others, 1996).

### Deposition

Ash3d tracks the mass flux of each grain size across cell boundaries and accumulates a deposit once tephra falls through the cell boundary that represents the ground surface (mean sea level) at a location.

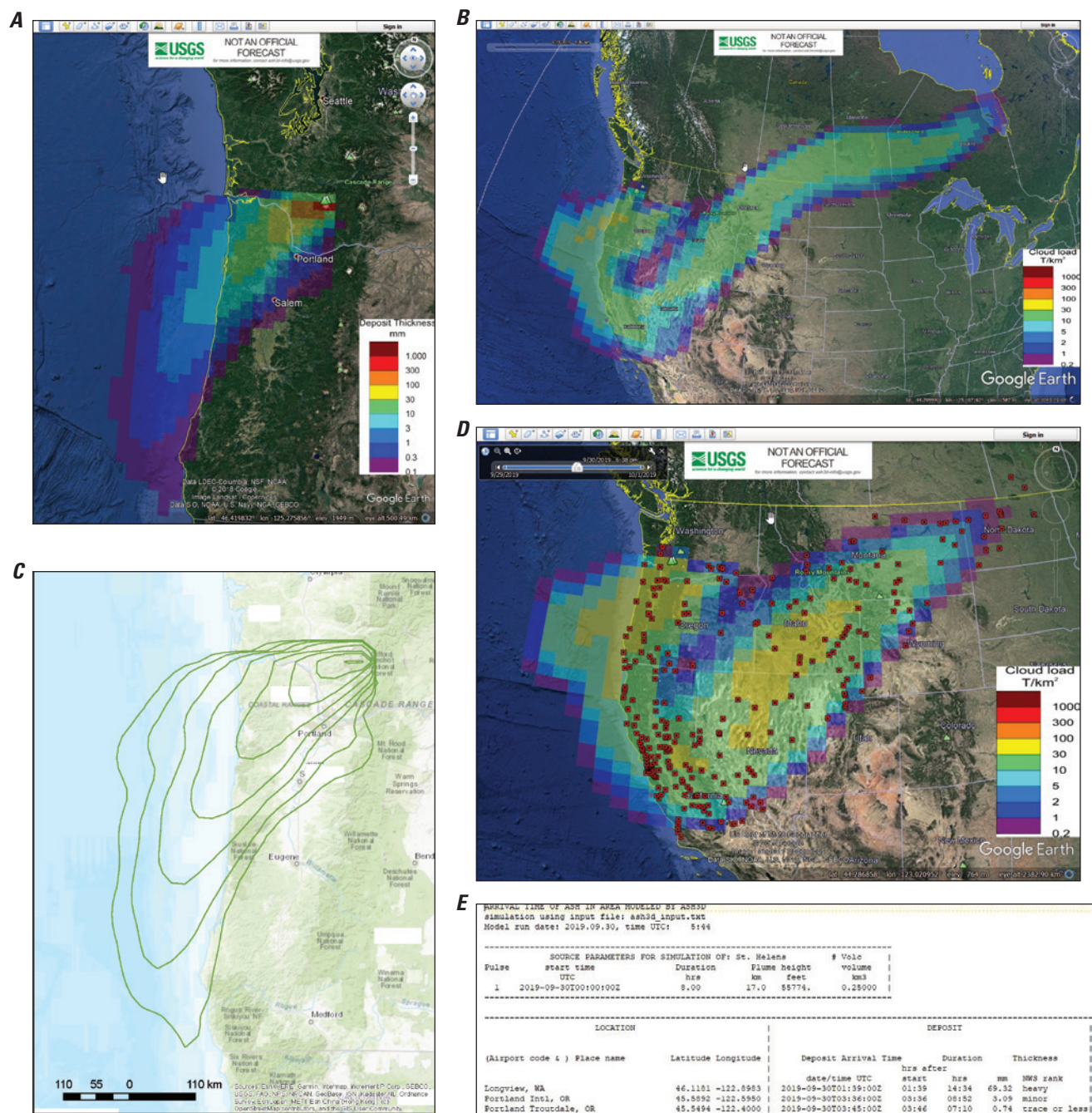
### Examples of Model Output

Ash3d output includes visualizations of the deposit (fig. 2A) and of the moving cloud (fig. 2B), that can be opened in Google Earth, as well as gridded ASCII files of deposit or cloud, shapefiles that can be imported into GIS software such as ArcMap® (fig. 2C), and kmz (fig. 2D) or text (fig. 2E) files illustrating the arrival time and thickness of tephra at airports or other locations.

### The Web Interface

Ash3d was written in Fortran 90/95. The program and associated scripts are executed on a Linux operating system and have been used to simulate and investigate eruptions since 2010. For the web interface described here, we have simplified the program for rapid use in operational settings by limiting the options to a few that are critical: volcano name, plume height, eruption start time, duration, erupted volume, and number of hours of simulation. We also automatically adjust the model resolution so that usable results can be obtained in about 10 minutes or less.





**Figure 2.** Examples of Ash3d output from simulations of a Mount St. Helens event. *A*, Deposit thickness illustrated in Google Earth. *B*, Cloud mass load in Google Earth. *C*, Contours of deposit thickness (green contours) in ArcMap®. Contour values are the same as the boundaries of the colored regions in figure 2A: 0.1, 0.3, 1, 3, 10, 30, and 100 mm respectively from outer to inner. *D*, Cloud mass load and airports impacted (red squares) in Google Earth. *E*, Table of deposit thickness and arrival time at airports.

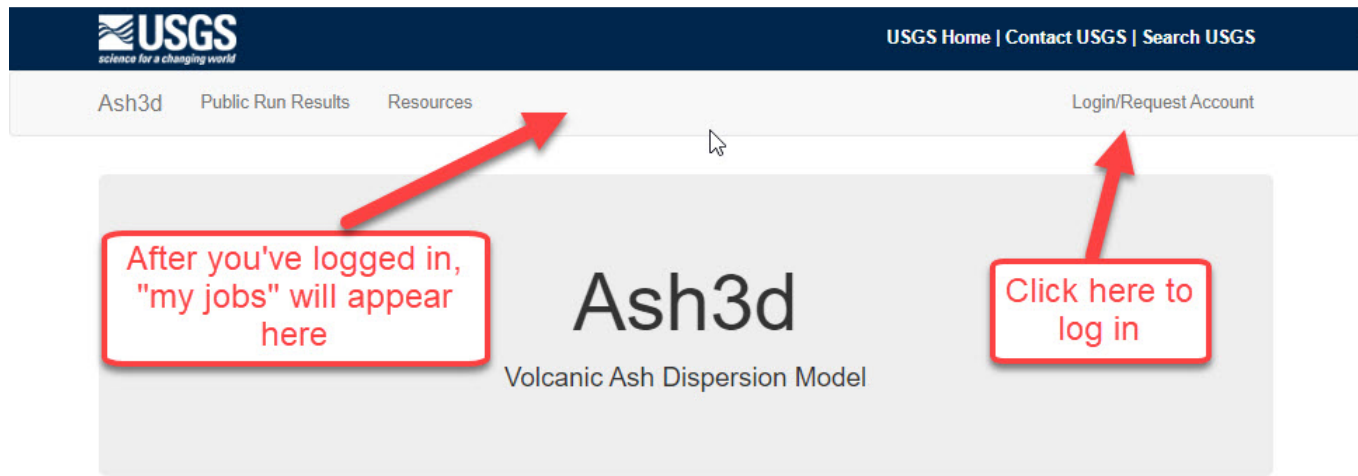
## Accessing the Interface

The Ash3d web interface is located at <http://vsc-ash.wr.usgs.gov>. At this page (fig. 3), click on “Login/Request account” (upper right) to log in or request an account.

After logging in with a username and password assigned to you, you can click on “My Jobs” at the top of the page as shown in figure 3 and you will see a home page (fig. 4A). All

Ash3d pages can be resized to fit comfortably on computers, smartphones or tablets (fig. 4B).

Under “My Jobs”, you will see a list of jobs that you have executed. Jobs that have been run in the last 5 days, such as the “Coso scenario run” and “Rainier mid-sized event” in figure 4A, will show a link to results. Older jobs (>5 days) are deleted automatically, but you can re-run them by clicking “Run” in the second column.



### The Ash3d Volcanic Ash Dispersion Model

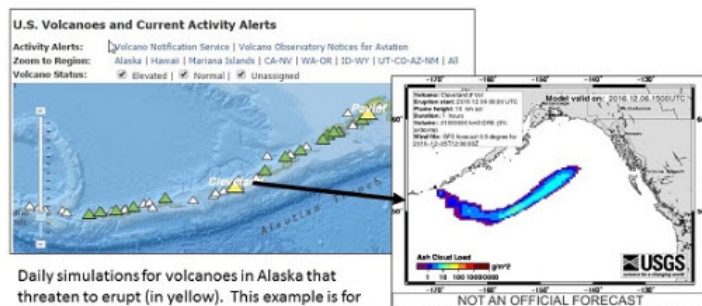
During explosive eruptions, volcanic ash can disrupt downwind populations by causing breathing problems, clogging air filters, shorting out power systems and making transportation difficult. Volcanic ash clouds can threaten air traffic by sandblasting windscreens, clogging pitot tubes, and in severe cases, causing jet engines to shut down.

Before and during eruptions, it is important to anticipate where ash clouds might move and deposits might fall. For this purpose, the U.S. Geological Survey has developed the Ash3d model. Ash3d uses three-dimensional, time-varying wind fields and other meteorological properties from numerical weather prediction models to calculate where airborne ash is transported under current or historical atmospheric conditions. Results are used in several ways.

**When volcanoes threaten to erupt**, the USGS runs daily simulations to anticipate where ash clouds may move or deposits might land. Model results are publicly posted, for example, at the [Alaska Volcano Observatory](#).



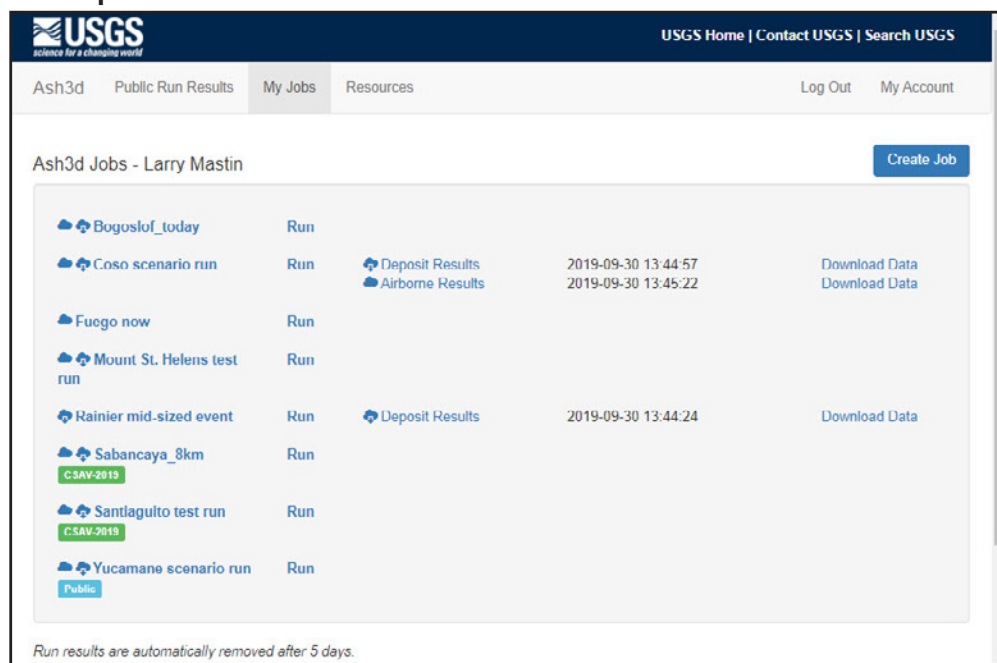
Ash plume drifting downwind from Cleveland Volcano, Alaska on May 3, 2006. Public photo taken from the International Space Station.



**Figure 3.** Screenshot of the Ash3d home page.



## A. Computer



## B. Phone

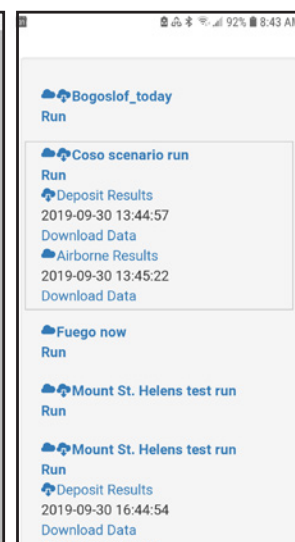


Figure 4. Screenshot showing the Ash3d jobs page. A, on a computer screen. B, on a smartphone.

Clicking on “Deposit Results” or “Airborne Results” (fig. 4A, third column) links to the results of a particular run. Clicking on “Download data” will allow you to download a zip file containing additional output files.

Note these features illustrated in fig. 4A:

1. There are two types of simulations; deposit simulations, indicated by a cloud icon with a downward-pointing arrow (☁️), produce a map and other information about the deposit (arrival time, and so on). Cloud simulations, indicated by a cloud icon (☁️), show the location and movement of the cloud.
2. The green icon labeled “csav-2019” (CSAV-2019) under the “Sabancaya\_8km” job indicates that the run results will be shared with the CSAV-2019 user group. Administrators can set up groups to share results with co-workers (for example others in a volcano observatory). Contact the Ash3d administrator ([ash3d-admin@usgs.gov](mailto:ash3d-admin@usgs.gov)) if you would like to set up a group.
3. The blue icon labeled “public” (Public) under the “Yacamane scenario run” indicates that the results will be posted on an Ash3d public page, which can be viewed without an Ash3d account. The public page can be accessed through the “Public Run Results” link at the top of the home page (fig. 3). The URL of the Public Run Results page and models listed therein can also be shared with non-Ash3d users. If you would like the ability to post public runs, contact the Ash3d administrator ([ash3d-admin@usgs.gov](mailto:ash3d-admin@usgs.gov)).

## Creating a New Job

To create a new job, click “Create Job” in the upper right corner of the “My Jobs” page (fig. 4A). A new “Create Ash3d Job” page will be generated (fig. 5), where the following fields can be filled out:

- ☐ **Name:** Name that you would like to apply to the current job
- ☐ **Run type:** You may choose either **airborne ash**, **ash deposit**, or **Both Airborne and Deposit**<sup>1</sup>

Airborne ash simulations use a single fine grain size (0.01 mm) with a negligible settling velocity and are intended to simulate only the movement of the cloud, not the settling of ash to form the deposit. For airborne simulations, the erupted volume in the ash cloud is set to 5 percent of the total erupted volume based on empirical studies suggesting a few to several percent of the erupted mass makes it into the distal cloud (Dacre and others, 2011; Devenish and others, 2012). Ash deposit simulations use seven particle sizes (4, 2, 1, 0.5, 0.25, 0.125, and 0.088 mm) and five aggregate sizes (0.2176, 0.2031, 0.1895, 0.1768, and 0.1649 mm), and optimize the size and resolution of the model domain to capture the structure of the deposit. If “both” is specified, Ash3d runs two simultaneous simulations, one for the deposit and another for the drifting cloud. After choosing these options, click “select volcano/site”.

<sup>1</sup> Depending on how your account was set up, you may see a fourth option, “Advanced Options.” The Advanced Options are experimental and not guaranteed to run without error. But if you would like to try the advanced options, contact us ([ash3d-admin@usgs.gov](mailto:ash3d-admin@usgs.gov)).

Figure 5. Screenshot of the Create Ash3d Job page.

## Selecting a Volcano or Site

After clicking “select volcano/site”, you will see the “Ash3d Sites” page, (fig. 6) where you can enter the name of a volcano in a search box. Type the name and then press “Submit Search” to search the Smithsonian Institution’s Global Volcanism Program (Global Volcanism Program, 2013) list of the world’s active volcanoes (those that have erupted during the Holocene). The name of your volcano will appear (fig. 6) if it is in the Smithsonian list under the name you’ve typed. If your volcano name has accents or diacritical marks (for example Lásca, Soufrière, Eyjafjallajökull), you may need to remove them before your volcano’s name appears. Additional eruption sites may be added by request, by sending an email to “ash3d-admin@usgs.gov”. After choosing a site, you will return to the “Create Ash3d job” page. Click “create job”.

Figure 6. Screenshot of the Ash3d Sites page, with the site chosen.

## Entering Source Parameters

The “Ash3d Job Edit” page (fig. 7) appears once you’ve entered a job name, run type, and volcano or site. The left side of this page contains entry fields for source parameters; the right side contains a box labeled “Model runs” with results from previous or current simulations, and a “Shared With” box that allows you to share results with a user group, (for example, the “CSAV-2019” group in fig. 7). Contact the Ash3d Administrator ([ash3d-admin@usgs.gov](mailto:ash3d-admin@usgs.gov)) if you would like to set up a group. For simulation duration, eruption duration, plume height, and erupted volume, default values are set for each volcano based on that volcano’s magma type and (or) eruption history (Mastin and others, 2009a, 2009b). Default values can be applied by clicking “apply” near the applicable text box.


Explanation of the inputs are given below. These explanations also appear when blue question marks (?) on the page are clicked.

**When complete:** You have the option of receiving an e-mail message when the run is complete. Note that some e-mail filters may filter out these automatic messages.

**Start Time:** You may choose from three options:

- **“Use time when the job runs”** assigns the current date and time as the eruption start time. To run simulations during actual eruptions, if you know exactly when the eruption started, use the third option (“Specific date and time”) to start a simulation.
- **“Hours after start of current NWP wind file”** is used primarily for simulations that are rerun automatically each time new wind files arrive (see “Power User Options” section) It assigns an eruption start time according to the number of hours after the most recently downloaded numerical weather prediction (NWP) forecast wind file. Forecast wind files are downloaded twice daily, for conditions starting at 0000 and 1200 UTC of that day. If the current wind file starts at 0000 UTC today, and you specify a start time of 00:30, the eruption start time will be at 0030 UTC today.
- **“Specific date and time”** opens a calendar that allows you to enter any date and time from January 1, 1948 to today. Using this option, if you choose an eruption start date and time that is more than two weeks ago, Ash3d will use a wind field taken from the global NCEP/NCAR Reanalysis 1 model with a 2.5 degree resolution. If you choose a more recent eruption start time, Ash3d will use recently downloaded NOAA GFS winds with a 0.5 degree resolution. Default date and time is UTC but may be changed to the time on your local computer by changing settings in the “My Account” link in the upper right-hand corner of this page.

**Simulation Duration:** This is the number of hours over which an ash cloud is tracked and is a required field. This value should be at least 6 hours but less than 144 hours. This


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[Ash3d](#)
[Public Run Results](#)
[My Jobs](#)
[Resources](#)
[Log Out](#)
[My Account](#)

### Ash3d Job Edit

Job Created By [Larry Mastin \(demo\\_power\\_user\)](#) [← Back](#)

**Name** ⓘ

**Run Type** ⓘ

Both Airborne and Deposit

**When Complete** ⓘ

▼

Model runs generally complete in about 10 minutes.

**Volcano/Site** ⓘ

**St. Helens**  
 Latitude: 48.200  
 Longitude: -122.183  
 Elevation: 2,549 m

**Start Time** ⓘ

▼

**Simulation Duration** ⓘ

Between 6 and 48 hours.

A value is required and must be between 6 and 48 hours.

Default simulation duration is 24.00 hours ([apply](#)).

**Eruption Duration** ⓘ

Between 0.1 and 24 hours.

A value is required and must be between 0.1 and 24 hours.

Default eruption duration is 3.00 hours ([apply](#)).

**Plume Height** ⓘ

km above sea level

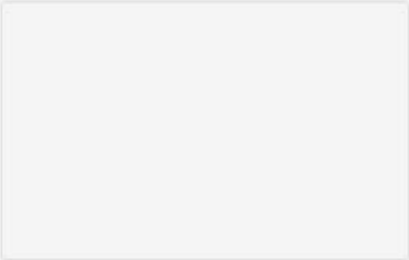
Default plume height is 14 km above sea level. ([apply](#)).

**Erupted Volume** ⓘ

km<sup>3</sup>

Value if unspecified:  
 DRE: airborne ash fraction = 5%  
 Default erupted volume is 0.0150 km<sup>3</sup> ([apply](#)).

**Model Runs**



Run results are deleted after 5 days.

**Shared With**

**Not Shared With**

CSAV-2019

+

**Figure 7.** Screenshot of the Ash3d Job Edit page.

value is used only for airborne ash simulations. You can apply the default simulation duration for your volcano by selecting the “apply” button. Deposit simulations automatically stop when 99 percent of the tephra has deposited.

**Eruption Duration:** The period of active ash emission is a required field. Enter a value between 0.1 and 24 hours. You can apply the default eruption duration for your volcano by selecting the “apply” button. Because Ash3d calculates erupted volume using plume height and duration, very short eruptions may produce too little ash to be visible in a cloud or a deposit map. For this reason, we do not allow eruption durations shorter than 0.1 hours.

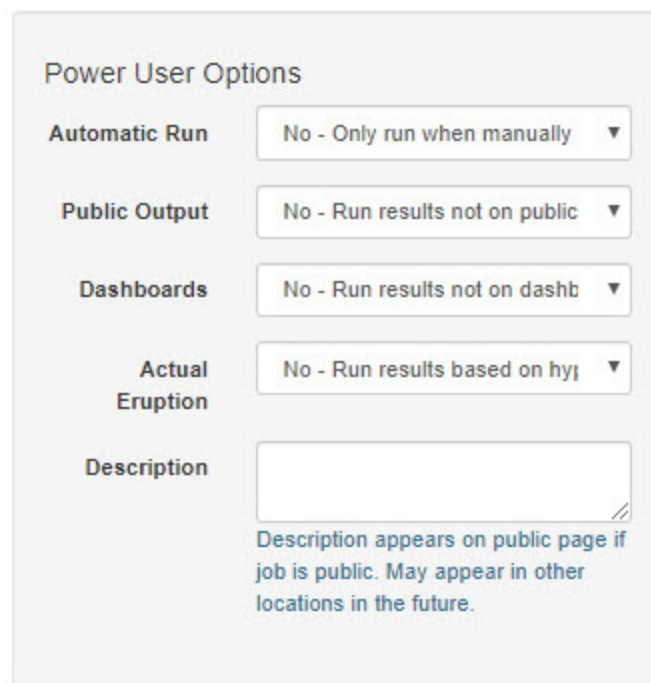
**Plume Height:** Values are given as feet or kilometers above sea level. Default units are in kilometers but may be changed to feet by changing settings in the “My Account” link in the upper right-hand corner of this page. The NOAA/NCEP models used by Ash3d extend to roughly 34 km above sea level. If you enter a higher plume, wind vectors at elevations greater than about 34 km are assumed to be the same as those at the highest pressure elevation. You can apply the default plume height for your volcano by selecting the “apply” button. When setting up eruptions using low plumes, please note the following: (1) local, low-level winds may not be very accurate using the GFS or NOAA/NCEP wind field; and (2) because the erupted volume is calculated using an empirical relationship between plume height and eruption rate, low plumes may produce so little ash that few contours are visible in the deposit or the cloud.

**Erupted Volume:** This is the total volume of erupted magma in cubic kilometers dense-rock equivalent (DRE). If no value is entered, the volume is automatically calculated from the plume height, eruption duration, and volcano summit elevation using the empirical relationship between plume height and eruption rate from Mastin and others (2009b, eq. 1). If the volume calculated is less than 0.0001 km<sup>3</sup>, the volume is set to 0.0001 km<sup>3</sup> to prevent errors.

## Power User Options

Users who issue forecasts as part of their job, for example staff of volcano observatories and volcanic ash advisory centers (VAACs), may be granted “Power User” status, which allows additional options. Contact the Ash3d Administrator ([ash3d-admin@usgs.gov](mailto:ash3d-admin@usgs.gov)) if you would like to be a Power User. Those options appear in a gray box at the bottom of the Job Edit page (fig. 8):

**Automatic Run:** Choose “yes” in this dropdown list to have the model rerun automatically when new wind files are downloaded. This feature can be used during periods of volcanic unrest, by providing an up-to-date forecast of where ash might go if an eruption were to occur today. If you use this option, you must specify the eruption start time using “Use



**Power User Options**

**Automatic Run** No - Only run when manually ▼

**Public Output** No - Run results not on public ▼

**Dashboards** No - Run results not on dashb ▼

**Actual Eruption** No - Run results based on hy ▼

**Description**

Description appears on public page if job is public. May appear in other locations in the future.

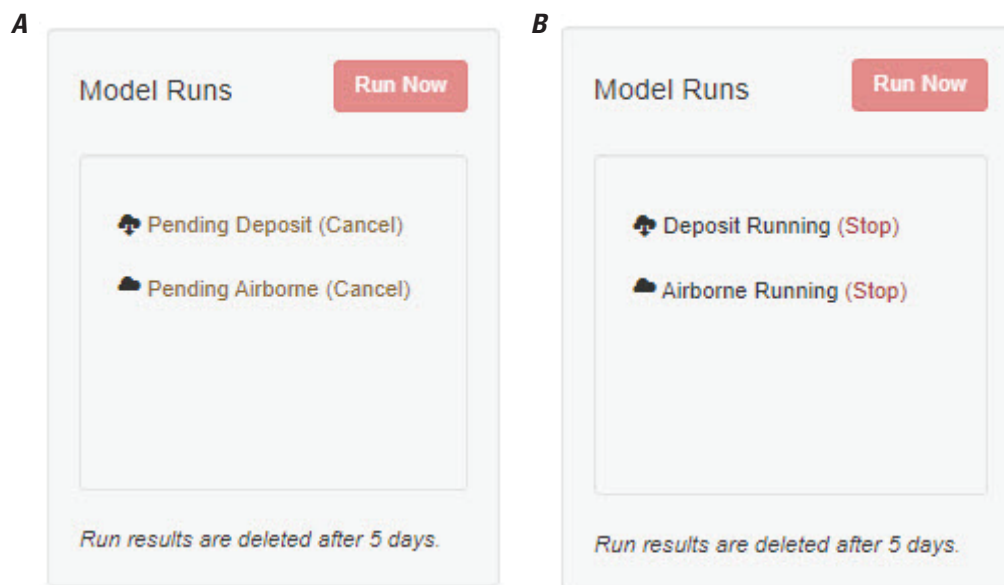
**Figure 8.** Screenshot showing the Power User Options on the Job Edit page.

time when the job runs” or “Hours after start of current NWP wind file” option, to ensure that the eruption start is always on the current day. New wind files are downloaded twice daily, at roughly 0500 UTC (for the 0000 UTC wind file) and 1700 UTC (for the 1200 UTC wind file). That is, we typically get each wind file about five hours after the current posting time. To ensure that new simulations are always for a future time, use the “Hours after start of current NWP wind file” setting, and set the eruption start time to at least 06:00. **NOTE:** automatic runs are executed indefinitely, whenever a new wind file arrives, until you deselect the Automatic Run option or delete this job.

**Public Output:** This feature allows the user to post the model output on the “Ash3d Public Run Results” page (<https://vsc-ash.wr.usgs.gov/ashgui/#!/publicruns>), where it can be accessed by anyone, with or without an Ash3d account. Publicly posted automatic daily runs have a static URL that can be scripted to grab the output and posted on another site, for example for observatories that wish to use Ash3d output on a web page of current activity (see for example the Cascades Volcano Observatory page of daily simulations for Mount St. Helens, <https://www.usgs.gov/media/images/ash-cloud-simulation-eruption-size-5181980-mount-st-helens-0>).

**Other Power User options:** The options for “Dashboards”, “Actual Eruption”, and “Description” are used only by the staff of USGS volcano observatories.





**Figure 9.** Screenshot showing the Model Runs box, which appears in the “Ash3d Job Edit” page. Jobs may be either pending (A) or running (B). Older jobs that have already run may also be in the list.

## Running the Model

Once the input parameters are set, and the “Save Changes” (lower right, fig. 7) and “Run Now” (upper right, fig. 7) buttons are pressed, the job appears in the “Model Runs” box on the Ash3d Job Edit page (fig. 9). The job is initially “pending” (fig. 9A), then “running” (fig. 9B) and can be stopped or cancelled by clicking “Stop” or “Cancel”. Jobs typically take less than about 10 minutes to run unless many jobs are in the queue, which is common after new wind files arrive; typically, around 0500 or 1700 UTC every day.

**NOTE:** at the present time (April 2021), airborne simulations typically complete in 2–3 minutes. Deposit simulations may take 10 minutes or so owing to the larger number of grain sizes whose movement must be calculated and the time required to run the model. Run times typically increase with plume height and eruption duration.

## Model Domain

As a Eulerian model, the geographic area covered by the model must be specified prior to execution. This presents a challenge; we want the domain to cover the area of the cloud or deposit, which could be any direction of the volcano depending on wind direction; but we do not know the direction of ash advection prior to the simulation. In order to set the model domain, we run a preliminary simulation at very low resolution

( $25 \times 25 \times 10$  cells) over an area centered on the volcano that is large enough to completely cover the cloud or deposit. This simulation generally takes less than 1 minute to run. The calculated area of the deposit or cloud is then used to outline a smaller domain that is run at higher resolution ( $100 \times 100 \times 10$  cells). This second simulation produces the final output.

## Model Results Page

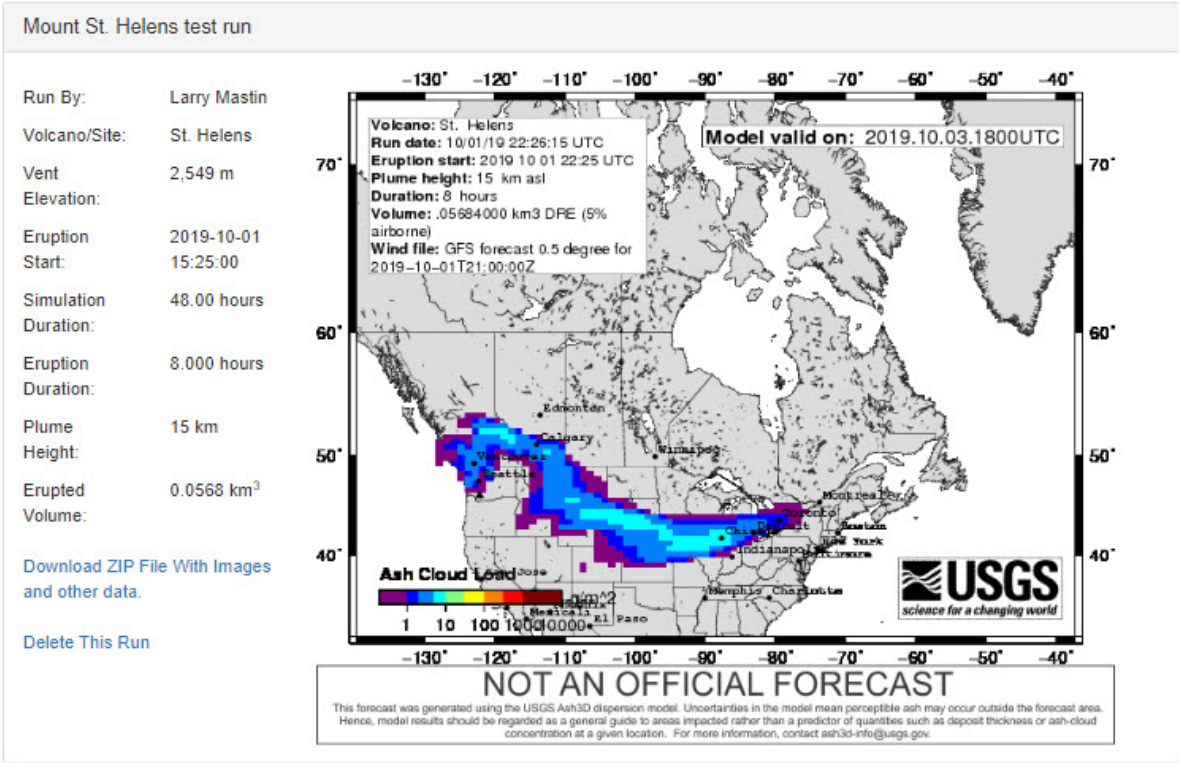
Upon completion, the jobs in the “Model Runs” box turn blue and change to hyperlinks to a Results page (fig. 10), which features:

- A sidebar (left) giving source parameters, the date and time of simulation, and a link to additional model output.
- A gif image (right) showing the deposit or, for airborne simulations, the moving cloud.
- A list of airports impacted (bottom). For airborne simulations, this list includes the arrival time of the cloud and the number of hours during which the cloud remains overhead. For deposit simulations, the list includes the arrival time of ash on the ground, the duration of ash fall, and the final deposit thickness.

A link to the left downloads a zip file containing additional files (table 1).

Ash3d Airborne Ash Results

[← Back](#)



**Table 1.** Files included in the zip file of model output.

[A, files generated during airborne simulations; D, files generated during deposition simulations.]

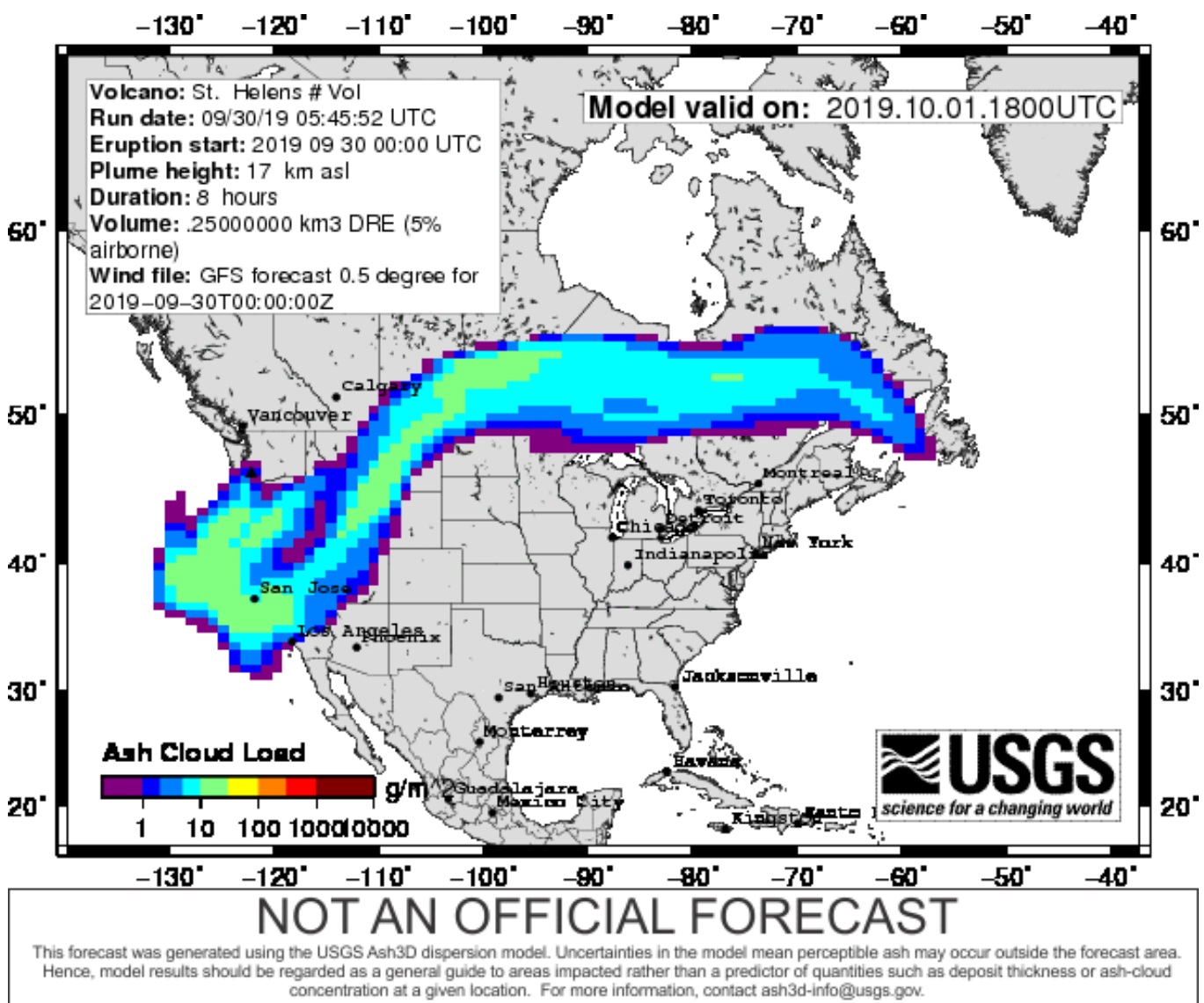
File name	Simulation Type	Description
ash_arrivaltimes_airports.kmz	D	kmz file showing the locations of airports over which the ash cloud has moved or where the deposit has landed.
ash3d_input.txt	A, D	ASCII input file used to run this model. An annotated example is given in the appendix.
ash3d_runlog.txt	A, D	System output log
Ash3d_Users_Guide.pdf	A, D	A copy of this user manual.
ashfall_arrivaltimes_airports.txt	D	Text file giving the arrival time of the deposit at airports, the final deposit thickness, and the number of hours the ash will be depositing. Contents of this file are also displayed in the Results page of the web interface.
ashfall_arrivaltimes_hours.kmz	D	Static map of deposit arrival time in hours after the eruption start.
cloud_load_animation.gif	A	Animated map of cloud movement, with shading that represents mass load (in grams per square meter). This animation is also displayed in the Results page of the web interface.
cloud_arrivaltimes_airports.kmz	A	kmz file showing the locations of airports over which the ash cloud has moved. Airports are denoted by red markers.
cloud_arrivaltimes_airports.txt	A	Text file giving the arrival time of the ash cloud at airports and the number of hours the cloud remains overhead. Contents of this file also are displayed in the Results page of the web interface.
cloud_arrivaltimes_hours.kmz	A	Static map of cloud arrival times in hours after the eruption start.
CloudConcentration.kmz	A	Animation of cloud movement. Colors indicate maximum ash concentration in a column of cells at a given x, y location.
CloudHeight.kmz	A	Animation of cloud movement. Colors indicate height of the cloud top at a given x, y location.
CloudLoad.kmz	A	Animation of cloud movement. Colors indicate integrated mass load of the cloud, in tonnes per square kilometer (for comparison with the animated gif, $1 \text{ T/km}^2 = 1 \text{ g/m}^2$ ).
deposit_thickness_inches.gif	D	Map showing contours of deposit thickness in inches. This image is also displayed in the Results page of the web interface. Zones are colored for trace, minor, substantial, and so on, as given in guidelines by the U.S. National Weather Service (2011).
deposit_thickness_inches.kmz	D	Static map of deposit thickness in inches, with zones colored for trace, minor, substantial, and so on, as given in guidelines by the U.S. National Weather Service (2011).
deposit_thickness_mm.gif	D	Map showing deposit thickness in contours of 0.1, 0.3, 1, 3, 10, 30, 100, and 300 mm.
deposit_thickness_mm.kmz	D	Map of final deposit thickness in millimeters.
deposit_thickness_mm.txt	D	ASCII gridded output of deposit thickness (mm). The file header gives the number of rows and columns, the latitude and longitude of the cell center in the lower left corner of the grid, the x and y cell size in degrees, and the no-data value. The gridded data lists 10 numbers per line in the file; thus a row in the model containing 100 cells will have its output split among 10 lines in the output file. A blank line in the output file separates model rows. The rows are ordered from south to north.
dp_mm_shp.zip	D	Zipped shape file of the deposit thickness in millimeters, for use in GIS applications. Contours are 0.1, 0.3, 1, 3, 10, 30, 100, and 300 mm.
dp_shp.zip	D	Zipped shape file of the deposit thickness in inches, for use in GIS applications. Contours are 1/256, 1/32, 1/4, 1, and 4 inches.
Time-stamped gif files (for example 2019.10.01.2100UTC_xxxx.gif)	A	Maps of cloud properties at different times. The time of the image is given in the file name (for example, 2019.10.01.2100UTC_cloud_load.gif) and in the upper right-hand corner of the gif image. The time interval between these images may be 0.5, 1, 2, 3, or 6 hours depending on the length of the simulation. As indicated in the file name, images show cloud mass load and cloud height. File names with a time stamp followed by “_puff.gif” (for example, 2019.10.01.2000UTC_puff.gif) give results from a simultaneous simulation of the puff dispersion model (Searcy and others, 1998). The ash cloud is depicted by a cloud of colored particles, with colors indicating the height in the cloud.

## Model Output Files

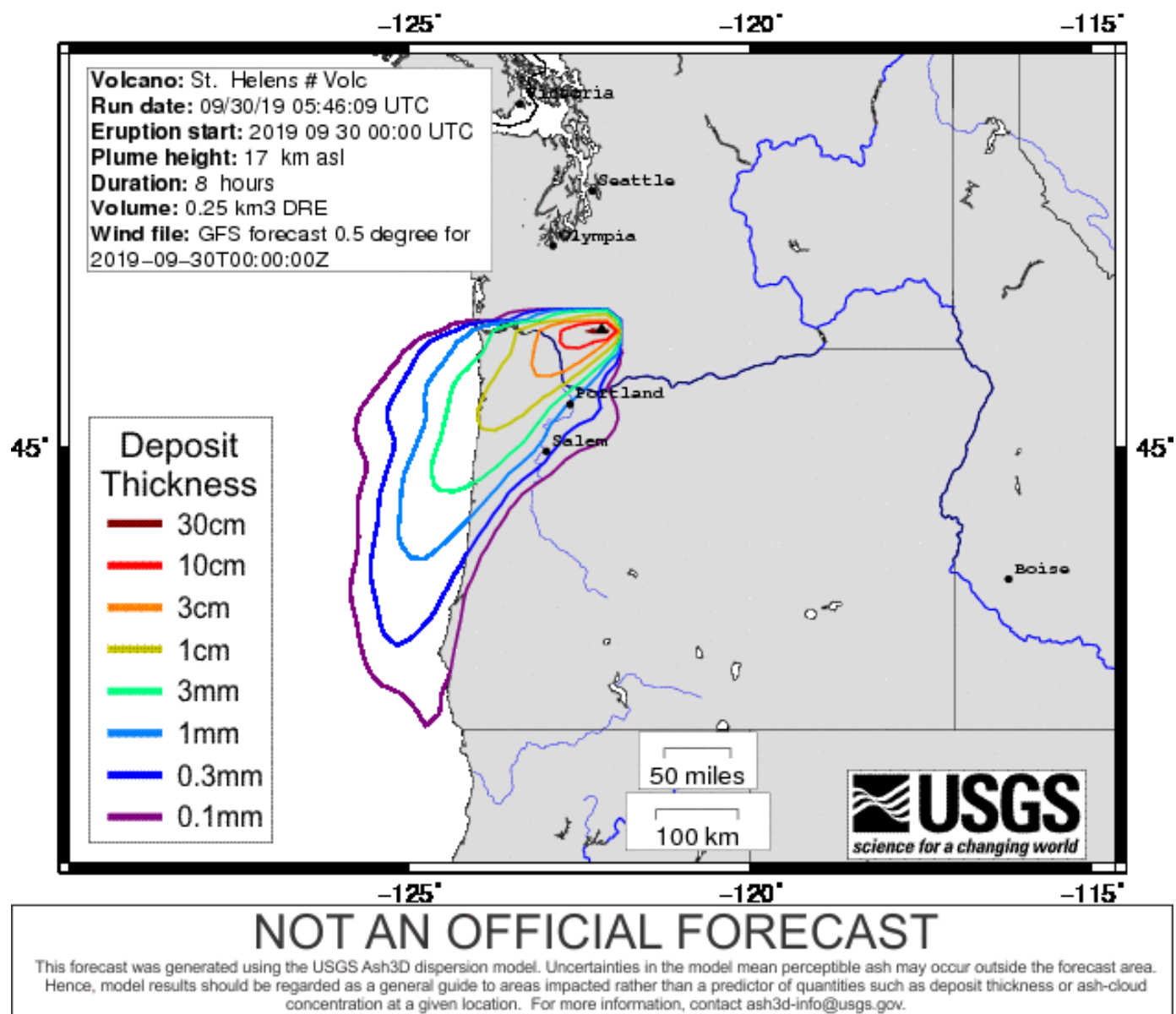
### Gif Images of the Ash Cloud or Deposit

The output from airborne ash simulations includes a series of gif files showing the location of the cloud at a given time with shading for ash mass load (fig. 11) or cloud height. An animated gif image (cloud\_animation.gif) is generated by combining the static images of ash mass load. In order to see the animation, you may need to open the gif image with Microsoft Internet Explorer or freeware such as IrfanView, as many default picture viewers will not show the animation.

The output from deposit simulations includes two gif images of the deposit. One (deposit\_thickness\_mm.gif, fig. 12) shows thickness contours in millimeters (0.1, 0.3, 1, 3, 10, 30, and 100 mm). Another (deposit\_thickness\_inches.gif) shows thickness in inches with labels for “trace,” “minor,” “substantial,” “heavy,” and “severe,” ashfall as defined by the USGS and the U.S. National Weather Service (Federal Aviation Administration). Ash3d calculates mass load of the deposit ( $\text{kg m}^{-2}$ ), and then converts to deposit thickness assuming a deposit density of  $1,000 \text{ kg m}^{-3}$ . Measured densities of real deposits range from less than 500 (Sarna-Wojcicki and others, 1981) to greater than  $1,300 \text{ kg m}^{-3}$  (Scollo



**Figure 11.** Gif image of an ash cloud from Mount St. Helens. The source parameters for this run are in the explanation at the upper left. The current time (that is, the date and time when the cloud is calculated to be at the location shown) is given in the upper right.



**Figure 12.** Gif image of deposit thickness from a simulation from Mount St. Helens. Eruption source parameters are on the upper left.

and others, 2007). Using a density of  $1,000 \text{ kg m}^{-3}$ , the deposit thickness in millimeters is numerically equal to the mass load in kilograms per square meter ( $\text{kg m}^{-2}$ ).

### Zipped Keyhole Markup Language (kmz) files

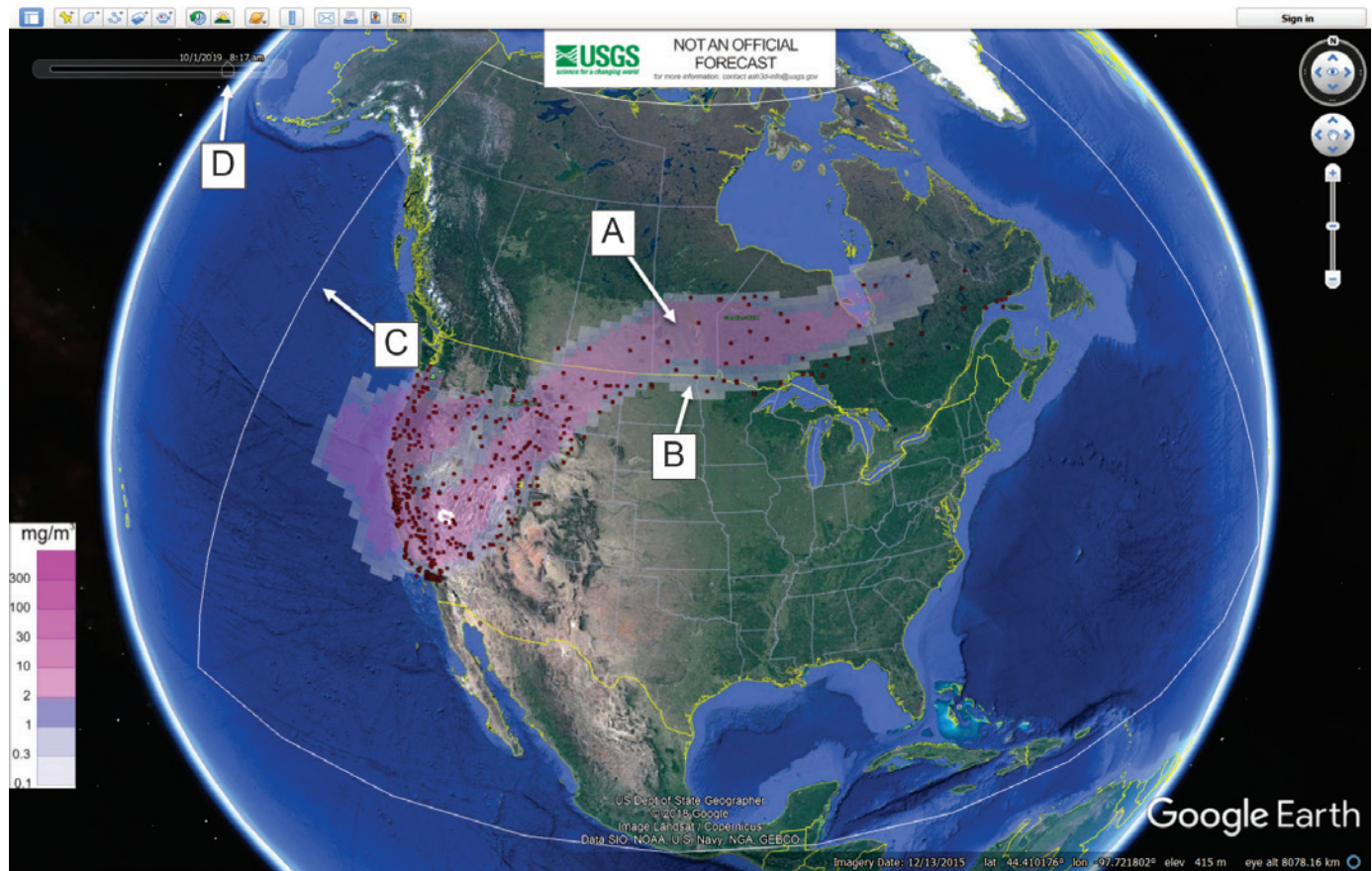
Files having the suffix .kmz can be opened by Virtual Globes software such as Google Earth. These are zipped keyhole markup language (kml) files that graphically display

animations of cloud movement, cloud or deposit arrival times, the thickness distribution of the deposit, and arrival times of ash at airports.

### Viewing kmz files in Google Earth

Using an example eruption from Mount St. Helens, figure 13 illustrates the location of the cloud as displayed by the file CloudConcentration.kmz. The movement of the cloud



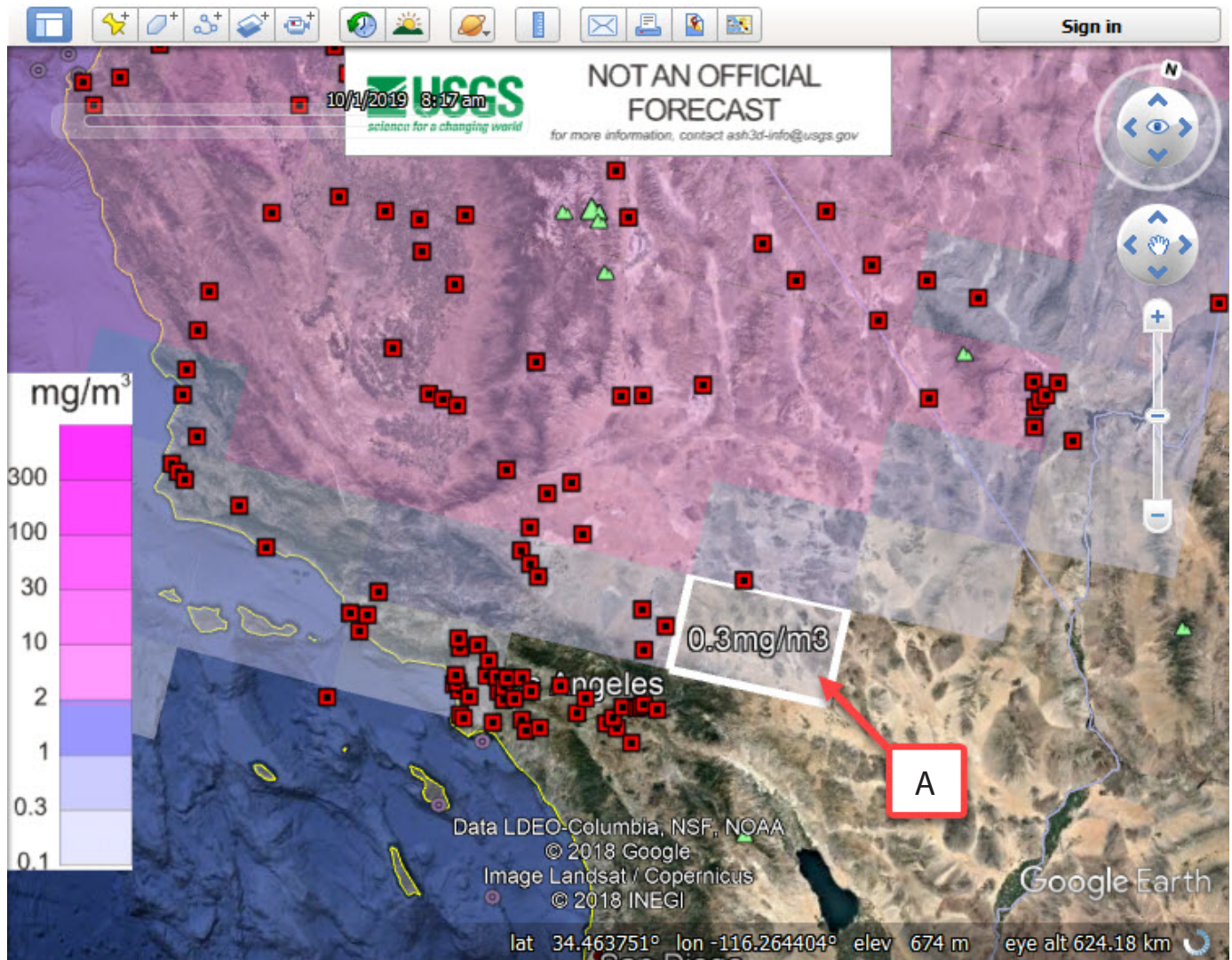


**Figure 13.** Screenshot showing Google Earth view of model output from a Mount St. Helens simulation from the files CloudConcentration.kmz and cloud\_arrivaltimes\_airports.kmz. Cloud concentration (in milligrams per cubic meter [ $\text{mg}/\text{m}^3$ ]) is shown in pink (A); impacted airports shown as red boxes (B); the model boundary is shown by the white box (C). Cloud movement can be animated using the time slider (D).

and the appearance of impacted airports can be animated using the time slider in the upper left (D in fig. 13). The cloud that is visible in the Google Earth window is a set of polygons, each of which has the size and location (in two dimensions) of one of the cells in the Ash3d model. When viewed obliquely in

Google Earth, these polygons are located at an elevation that corresponds to the top of the cloud.

To view the concentration at a location in the cloud, place the mouse over that location. When zoomed in, the boundaries of that node will appear (A in fig. 14), and the concentration



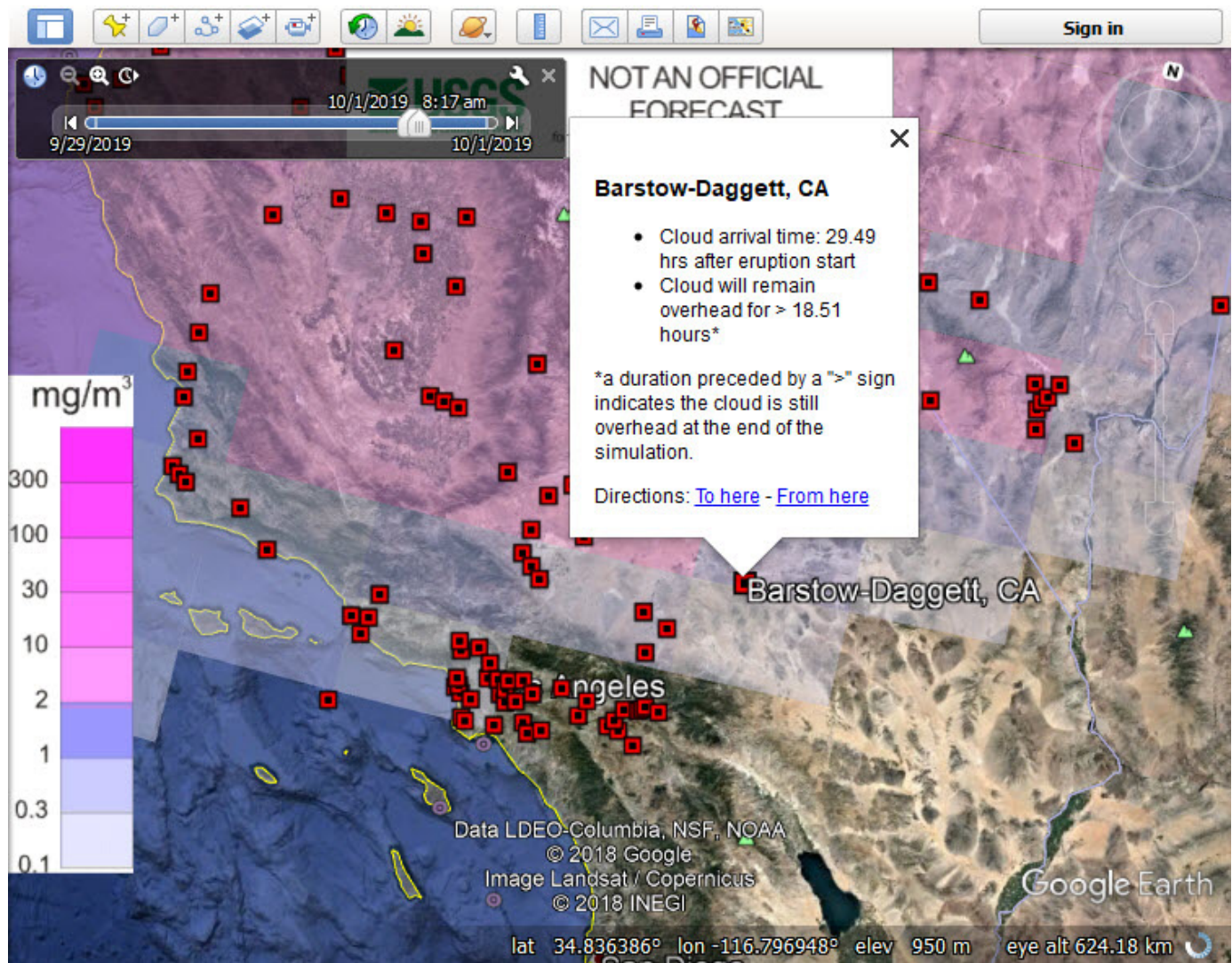
**Figure 14.** Screenshot showing mousing over a cloud polygon causes its outline to appear (A) and its value (here ash concentration) to be displayed. Red boxes are airports.

value will be displayed. This display is a 2D representation of the 3D cloud, hence the value of ash concentration displayed is the maximum in a vertical column of nodes at that x and y location. Deposit thickness, cloud load, and other properties are similarly displayed in other kmz files.

Locations of airports (red boxes) impacted by ash also are shown in figure 14 (from the file `cloud_arrivaltimes_airports.kmz`). Placing the mouse arrow over any of the airport

symbols causes the airport name to be displayed, and clicking on an airport symbol opens a dialog box (fig. 15). For airborne simulations, the box displays the arrival time of the cloud and the number of hours the cloud remains overhead. For deposit runs, it displays the deposit arrival time and a plot of thickness versus time at that location. In deposit simulations, white symbols denote airports where greater than 0.1 mm deposit has accumulated.





**Figure 15.** Clicking on an airport symbol opens a dialog box giving the arrival time of the ash cloud or deposit. Red boxes are airports.

## Troubleshooting kmz animations

Occasionally animations do not display properly when viewing a kmz file. Common problems are:

- **The clouds from all times are overlapping in the Google Earth window.** Ensure that the two caliper pincers on the time slider (A in fig. 16) are pressed together. If they are not, the timeline is set to display a time range rather than a point in time.
- **Pressing the animation button does not make the cloud appear.** Check the timeline to make sure that the start and end times displayed correspond to the beginning and end of the simulation. If they indicate a larger time span, you may have another folder checked in “My Places” or “Temporary Places” on the left sidebar.

Make sure that all other folders with time data are unchecked and try the animation again.

- **The animation runs too slowly or too fast, or does not loop.** These settings can be adjusted by clicking on the wrench icon (B in fig. 16) on the timeline.



**Figure 16.** Close-up screenshot of the time slider in Google Earth. (A) points to the adjustable calipers on the time slider and (B) points to the settings icon.

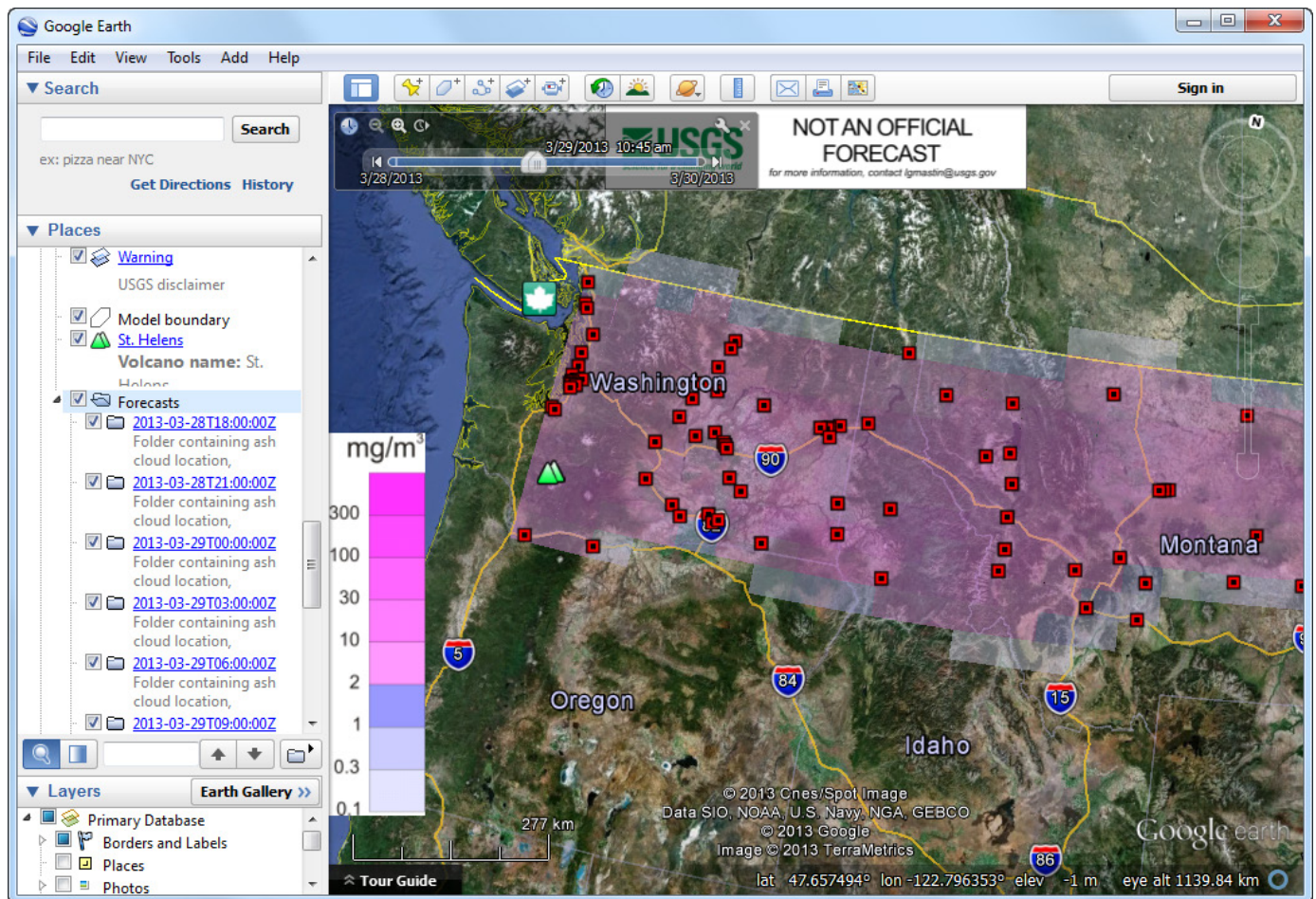


## Manipulating the Contents of a kmz file

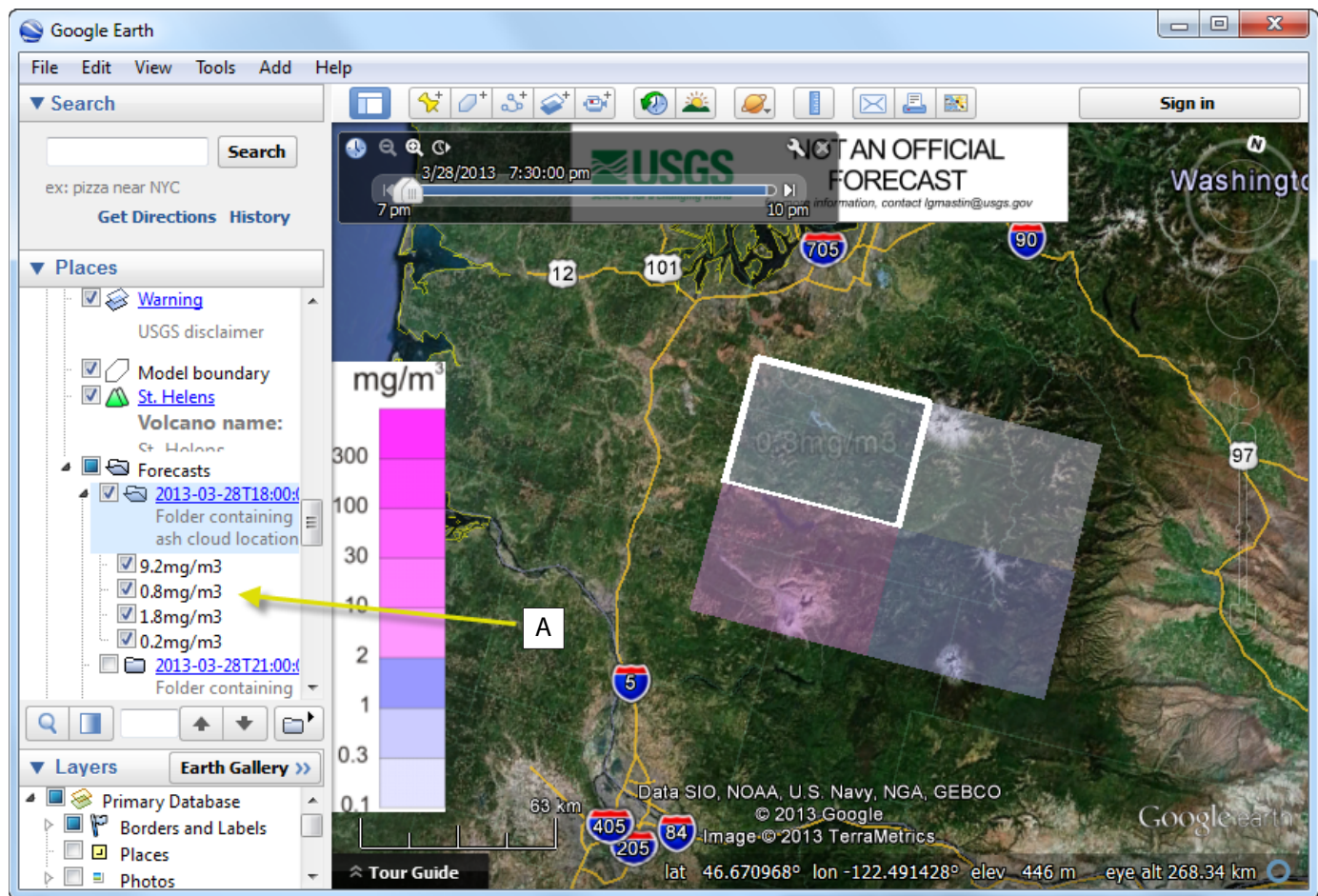
On the left sidebar of Google Earth, under “Temporary Places,” one can view the contents of the kmz file (fig. 17). The contents include a legend, a graphical USGS disclaimer, the model boundary, and a folder containing forecasts. Each subfolder in the Forecasts folder contains an image of the cloud at a time that is specified by the folder name, in

year, month, day, hour, and minute (UTC). To view the cloud at just one of these specified times, uncheck the box next to the Forecasts folder, and then check a box next to a single subfolder.

Individual polygons in a subfolder also may be displayed (fig. 18) by right-clicking that subfolder, choosing “Properties,” and checking the box labeled “Allow this folder to be expanded.”



**Figure 17.** Google Earth window with left sidebar visible, illustrating the contents of the CloudConcentration.kmz file. Red boxes are airports.



**Figure 18.** Google Earth window illustrating the contents of the CloudConcentration.kmz file, with a subfolder set so that individual polygons can be viewed in the left sidebar (A).

## Limitations of the Graphical User Interface (GUI)

In building an interface that can be used easily by users around the world, we had to make some compromises that limit the accuracy and (or) resolution of the model in certain circumstances. Some of the key limitations are as follows:

**Horizontal grid resolution.**—The grid resolution of the Ash3d model is set automatically to 100×100 nodes, as a compromise that produces realistic-looking output but also ensures that the simulations run in several minutes or less.

**Vertical grid resolution.**—Model speed is highly sensitive to vertical grid resolution. The vertical spacing is set to 10 percent of the plume height between sea level and the plume top, with the model domain extending to 1.3 times the plume height. For example, for a plume height that is 7 km above sea level, the cell tops will be at 0.7, 1.4, 2.1, 2.8, 3.5, 4.2, 4.9, 5.6, 6.3, 7.0, 7.7, 8.4, and 9.1 km respectively. This can lead to limitations for low plumes at tall volcanoes. For example, Sabancaya in Peru has a summit elevation of about 6 km. A plume rising 1 km above its summit, for example, would have the vertical cell spacing listed above. Only one

cell, from 6.3- to 7.0-km elevation, and part of the cell below it, would fully contain the plume. Downwind advection from this cell would not resolve vertical variations in wind.

**Resolution of wind data.**—The NOAA GFS 0.5-degree wind field used by the graphical user interface (GUI) has a horizontal grid resolution of 0.5 degrees latitude and longitude, and about 0.2 km vertically at ground level, decreasing in resolution with height. It cannot resolve local or low-level features such as valley winds in mountainous terrain. Temporally, new GFS data are generated every 3 hours, although we download it only twice daily (the 0000 and 1200 UTC files). Much higher resolution wind data are available from national meteorological agencies for specific regions, and can be read by Ash3d in command-line modeling, but we can't easily incorporate it into our global interface. In addition, bandwidth limitations have motivated our decision to download new data only twice daily. These limitations are most severe when modeling small eruptions, especially in mountainous terrain, or eruptions in a rapidly changing wind field.

**Fixed grain size distribution.**—For deposit simulations, the grain-size distribution is automatically set to a simplified set based on a Mount St. Helens grain-size distribution (Mastin and others, 2016). Ash finer than about 0.06 mm is represented



in the model as aggregates having a median size of 0.19 mm and density of 600 kg/m<sup>3</sup>. Because the fine ash is aggregated, the deposit footprint is not highly sensitive to the amount of fine ash in the erupted mass, but eruptions whose grain-size distribution differs significantly from that used here may still produce deposits that differ from those predicted.

*Fixed vertical distribution of mass in the plume.*—Plumes that fluctuate in height may distribute ash over a wider range of elevations than fixed height plumes and produce ash clouds or deposits whose distributions differ. These differences cannot be considered in the simplified GUI.

*Inability to adjust output settings such as thickness contours on isopach maps.*—Deposit thickness is represented in the GUI by isopachs whose values (in metric units) are 0.1, 0.3, 1, 3, 10, 30, 100, and 300 mm. Thin deposits from small eruptions may be depicted by only one or two contour lines in model output.

*No topography.*—Ash3d uses a crude cut-cell technique that represents topography as a brickwork of stair-stepping cells. In mountainous terrain this technique can produce artifacts such as ash accumulation on the windward sides of mountain ranges. For this reason, we have turned off topography in the GUI. In most cases the omission of topography has no significant effect, but in mountainous terrain or at high altitude the effects can be greater.

## Concluding Remarks

Ash3d is in a continual state of development. This document explains the capabilities of the model in its current form. This document may be revised as the model and interface evolve.

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## Appendix: Example Ash3d input file

In the example input file below, blue text are comments in the input file; black text are input values. All comments are preceded by a hash (#).

---

```
#The following is an input file to the model Ash3d,
#Created by L.G. Mastin and R. P. Denlinger, U.S. Geological Survey
#
#GENERAL SOURCE PARAMETERS. DO NOT DELETE ANY LINES
# LINE 1 of this block gives the volcano name or CAVW number.
#   If the CAVW number is given, Ash3d looks up the default eruption source
#   parameters for this volcano in the ESP table of Mastin (2009, USGS
#   Open-File Report 2009-1133)
# LINE 2 of this block identifies the projection used and the form of
#   the input coordinates and is of the following format:
#   latlonflag projflag (variable list of projection parameters)
#   projflag should describe the projection used for both the windfile(s) and
#   the input coordinates. Currently, these need to be the same projection.
#   For a particular projflag, additional values are read defining the projection.
#   latlonflag = 0 if the input coordinates are already projected
#   = 1 if the input coordinates are in lat/lon
#   projflag = 1 -- polar stereographic projection
#       lambda0 -- longitude of projection point
#       phi0  -- latitude of projection point
#       k0    -- scale factor at projection point
#       radius -- earth radius for spherical earth
#       = 2 -- Alberts Equal Area
#       lambda0 --
#       phi0  --
#       phi1  --
#       phi2  --
#       = 3 -- UTM
#       zone  -- zone number
#       north -- flag indication norther (1) or southern (0) hemisphere
#       = 4 -- Lambert conformal conic
#       lambda0 -- longitude of origin
#       phi0  -- latitude of origin
#       phi1  -- latitude of secant1
#       phi2  -- latitude of secant2
#       radius -- earth radius for a spherical earth
# LINE 5 gives the vent location. It can take either two or three variables
#   If two variables are given, they are taken to be x and y of the vent
#   If three are given, the third is taken to be vent elevation. If no
#   vent elevation is given, Ash3d uses the elevation of the topography
#   at this location (or zero, if topography is not used).
# LINE 8 gives the diffusion coefficient and a parameter determining the
#   vertical distribution of mass. The vertical distribution may be
#   specified by:
#   A numerical value for the Suzuki constant, assuming that the Suzuki
#   equation is used to specify the vertical distribution of ash in
#   the column of nodes above the volcano.
#   The word 'point' if all ash is to be concentrated in a single cell at
#   the plume top.
#   The word 'line' if ash is to be distributed evenly in the column of
#   nodes from the ground surface to the plume top.
***** BLOCK 1 *****
St. Helens      #Volcano name (character*30) (52.894N 170.054W)
1 1 -135.0 90.0 0.933 6371.229 #Proj flags and params
    -129.971    40.548    #x, y of LL corner of grid (km, or deg. if latlonflag=1)
    15.323     8.376     #grid width and height (km, or deg. if latlonflag=1)
    -122.183    46.200    #vent location (km, or deg. if latlonflag=1)
```

## 22 Ash3d User's Guide—A Three-Dimensional Model for Atmospheric Tephra Transport and Deposition

```
0.20430 0.11168 #DX, DY of grid cells (km, or deg.)
1.700      #DZ of grid cells (always km)
000. 4.    #diffusion coefficient (m2/s), Suzuki constant
1          #neruptions, number of eruptions or pulses
*****
#ERUPTION LINES (number = neruptions)
#In the following line, each line represents one eruptive pulse.
#Parameters are (1) start time (yyyy mm dd h.hh (UT)); (2) duration (hrs);
# (3) plume height; (4) eruped volume (km3)
#If the year is 0, then the model run in forecast mode where mm dd h.hh are
#interpreted as the time after the start of the windfile.
#Furthermore, if the duration, plume height or erupted volume is negative, it
# is replaced with ESP value for that volcano.
***** BLOCK 2 *****
0 0 0 0.00 8.00 17.00 0.2500E+00
*****
#WIND OPTIONS
#Line 1: iwind, iwindFormat. Ash3d will read from either a single 1-D wind
# sounding, or gridded, time-dependent 3-D wind data, depending on
# the value of the parameter iwind.
# For iwind = 1, read from a 1-D wind sounding
# 2, read from 3D gridded ASCII files generated by the Java script
# ReadNAM216forAsh3d or analogous.
# 3, read directly from a single NetCDF file.
# 4, read directly from multiple NetCDF files.
# The parameter iwindFormat specifies the format of the wind files, as follows:
# iwindFormat = 1: ASCII files (this is redundant with iwind=2)
# 2: NAM_216pw 45km files (provided by Peter Webley)
# 3: NARR_221 32km (see http://dss.ucar.edu/pub/narr)
# 4: unassigned
# 5: NAM_216 files from idd.unidata.ucar.edu
# 6: AWIPS_105 90km from idd.unidata.ucar.edu
# 7: CONUS_212 40km from idd.unidata.ucar.edu
# 8: NAM_218 12km
# 9: unassigned
# 10: NAM_242 11km http://motherlode.ucar.edu/
# 20: NCEP GFS 0.5 degree files
# (http://www.nco.ncep.noaa.gov/pmb/products/gfs/)
# 21: ECMWF 0.25deg for Hekla intermodel comparison
# 22: NCEP GFS 2.5 degree files
# 23: NCEP DOE Reanalysis 2.5 degree files
# (http://dss.ucar.edu/pub/reanalysis2)
# 24: NASA MERRA
# 25: NOAA/NCAR Global Reanalysis 1
# http://www.esrl.noaa.gov/psd/data/gridded/data.nmc.reanalysis.html
#Line 2: iHeightHandler. Many plumes extend higher than the maximum height
# of numerical weather prediction models. Ash3d handles this as
# determined by the parameter iHeightHandler, as follows:
# iHeightHandler = 1, stop the program if the plume height exceeds mesoscale height
# 2, write a warning to the log file if plume height exceeds mesoscale height
***** BLOCK 3 *****
4 20 #iwind, iwindFormat
2 #iHeightHandler
32.0 #Simulation time in hours
yes #stop computation when 99% of erupted mass has deposited?
34 #nWindFiles, number of gridded wind files (used if iwind>1)
*****
#OUTPUT OPTIONS:
#Lines 1-15 require "yes" or "no" indicating whether a particular file type is
# to be written out. The file types are given in the comments on
# each line.
#Line 16 indicates the type of 3-D ash concentration file to write, and is
```

```

#      used only if 'yes' is given in line 15. The options here are
#      'ascii', 'binary', or 'netcdf'.
#Line 17: nWriteTimes = the number of times output are to be written out
#      to the kml, ascii, or 3-D ash concentration files. Data
#      may be written out at uneven intervals (e.g. 0.2, 3, 3.4, and
#      12 hours after the eruption start) or at even intervals
#      (e.g. every two hours, starting 2 hours after the eruption start).
#      if nWriteTimes>0, the following line contains nWriteTimes
#      numbers specifying the times of output, in hours after the
#      eruption start.
#      if =-1, write times are assumed to be at even intervals. The time
#      interval in hours is given by a single number on the
#      following line.
#Line 18: WriteTimes = Hours between output (if nWritetimes=-1), or
#      times (hours since start of first eruption) for each output
#      (if nWriteTimes >1)
***** BLOCK 4 *****
yes  #Write out ESRI ASCII file of final deposit thickness?
yes  #Write out      KML file of final deposit thickness?
no   #Write out ESRI ASCII deposit files at specified times?
yes  #Write out      KML deposit files at specified times?
no   #Write out ESRI ASCII files of ash-cloud concentration?
no   #Write out      KML files of ash-cloud concentration?
no   #Write out ESRI ASCII files of ash-cloud height?
no   #Write out      KML files of ash-cloud height?
no   #Write out      ASCII files of ash-cloud load (T/km2) at specified times?
no   #Write out      KML files of ash-cloud load (T/km2) at specified times?
no   #Write ASCII file of deposit arrival times?
yes  #Write KML file of deposit arrival times?
no   #write ASCII file of cloud arrival times?
no   #Write KML file of cloud arrival times?
yes  #Write out 3-D ash concentration at specified times?
netcdf #format of ash concentration files      ('ascii', 'binary', or 'netcdf')
10    #nWriteTimes
      3.00 6.00 9.00 12.00 15.00 18.00 21.00 24.00 27.00 30.00      #WriteTimes (hours)
*****
#WIND INPUT FILES
#The following block of data contains names of wind files. The number of
#  lines in this block should equal nWindFiles as given in Block 3, line 5.
#  NOTE: If iWindFormat=25 in Block 3, line 1, then nWindFiles
#  should equal 1, and Block 5 should contain a single line giving
#  the path of the directory containing NCEP/NCAR Reanalysis files.
#  Subdirectories within this directory should be named by year.
***** BLOCK 5 *****
Wind_nc/gfs/latest/latest.f00.nc
Wind_nc/gfs/latest/latest.f03.nc
Wind_nc/gfs/latest/latest.f06.nc
Wind_nc/gfs/latest/latest.f09.nc
Wind_nc/gfs/latest/latest.f12.nc
Wind_nc/gfs/latest/latest.f15.nc
Wind_nc/gfs/latest/latest.f18.nc
Wind_nc/gfs/latest/latest.f21.nc
Wind_nc/gfs/latest/latest.f24.nc
Wind_nc/gfs/latest/latest.f27.nc
Wind_nc/gfs/latest/latest.f30.nc
Wind_nc/gfs/latest/latest.f33.nc
Wind_nc/gfs/latest/latest.f36.nc
Wind_nc/gfs/latest/latest.f39.nc
Wind_nc/gfs/latest/latest.f42.nc
Wind_nc/gfs/latest/latest.f45.nc
Wind_nc/gfs/latest/latest.f48.nc
Wind_nc/gfs/latest/latest.f51.nc

```

```

Wind_nc/gfs/latest/latest.f54.nc
Wind_nc/gfs/latest/latest.f57.nc
Wind_nc/gfs/latest/latest.f60.nc
Wind_nc/gfs/latest/latest.f63.nc
Wind_nc/gfs/latest/latest.f66.nc
Wind_nc/gfs/latest/latest.f69.nc
Wind_nc/gfs/latest/latest.f72.nc
Wind_nc/gfs/latest/latest.f75.nc
Wind_nc/gfs/latest/latest.f78.nc
Wind_nc/gfs/latest/latest.f81.nc
Wind_nc/gfs/latest/latest.f84.nc
Wind_nc/gfs/latest/latest.f87.nc
Wind_nc/gfs/latest/latest.f90.nc
Wind_nc/gfs/latest/latest.f93.nc
Wind_nc/gfs/latest/latest.f96.nc
Wind_nc/gfs/latest/latest.f99.nc
*****
#AIRPORT LOCATION FILE
#Lines 1-3 require 'yes' or 'no' indicating whether you would like to write out:
#   Line 1: an ASCII file listing the arrival time of ash at airports or
#           other locations listed in an airports file
#   Line 2: a listing of Grain-size distributions in the ASCII file of
#           ash arrival times at airports or other locations
#   Line 3: a kml file indicating the airports or other locations impacted
#           by ash, along with ash arrival times at those places
#   Line 4: The name of the file containing airports & other locations of
#           interest.
#   Line 5: whether to convert coordinates given in the airports file from
#           lat/lon to projected coordinates. (This option is no longer used:
#           coordinates in airport files are now assumed always to be in
#           latitude/longitude).
***** BLOCK 6 *****
yes      #Write out ash arrival times at specified locations to ASCII FILE?
no       #Write out grain-size distribution to ASCII airports file?
yes      #Write out ash arrival times to kml file?
         #Name of file containing airport or other locations
yes      #Have Proj4 calculate projected coordinates?
*****
#GRAIN SIZE GROUPS
#Line 1 contains an integer (nsize) that gives the number of size bins or
#   settling velocity groups. An optional second parameter (FV_ID)
#   may specify the fall model used. If no second parameter is given,
#   FV_ID=1 and the fall model of Wilson and Huang (1979, EPSL v.
#   44, pp. 311-324) is used, with a shape factor f=0.55 which is the
#   average of values measured by them. Other options for FV_ID are:
#   2 Wilson and Huang fall model with Cunningham Slip factor
#   3 W & H modification of Ganser (1993, Poder Tech., 77:143-152)
#   4 W & H modification of Pfeiffer and others (2005, JVGR 140:273-294)
#   5 Stokes flow for spheres with Cunningham slip
#Subsequent lines: there should be by nsize lines. If those lines contain:
#   2 numbers, Ash3d interprets them to be the mass fraction of particles in
#       that bin, and the settling velocity. It then calculates fall
#       assuming a constant settling velocity regardless of elevation.
#   3 numbers, Ash3d interprets them to be:
#       --size (mm) in that bin
#       --mass fraction in that bin
#       --density of particles (kg/m3) in that bin.
#   Ash3d calculates the settling velocity of each grain size as a
#   function of elevation using the formula of Wilson and Huang
#   (1979, EPSL, 44:311-324), assuming the particles have a shape
#   factor of f=0.44, which is the average of particles measured
#   by Wilson and Huang. This calculation also includes a slip

```



```

#      factor for small particles.
#      4 numbers, Ash3d interprets the first three as before. The fourth number
#      is assumed to be the shape factor f, defined by Wilson and
#      Huang as (b+c)/2a, where a, b, and c are the semimajor, inter-
#      mediate, and semiminor axes of an ellipsoid.
***** BLOCK 7 *****
12      #Number of settling velocity groups
2      0.06118 800 0.65      #Grain size, mass fraction, density, and shape factor f
1      0.07098 1040 0.65
0.5    0.22701 1280 0.65
0.25   0.21868 1520 0.65
0.1768 0.05362 1640 0.65
0.125  0.04039 1760 0.65
0.088  0.02814 1880 0.65
0.2176 0.018   600 1.0
0.2031 0.072   600 1.0
0.1895 0.12    600 1.0
0.1768 0.072   600 1.0
0.1649 0.018   600 1.0
*****
#Options for writing vertical profiles
#The first line below gives the number of locations (nlocs) where vertical
# profiles are to be written. That is followed by nlocs lines, each of which
#contain the location, in the same coordinate system specified above for the
#volcano.
***** BLOCK 8 *****
0      #number of locations for vertical profiles (nlocs)
*****
#netCDF output options
# Line 1: Name of the output file containing 3-D cloud structure
# Line 2: Title of this simulation as written in NetCDF 3-D output file
# Line 3: Optional comment for NetCDF 3-D output file
# Line 4: Indicates whether topography is to be used ("yes" or "no")
# Line 5: the first parameter is the toptofile format. This equals 1 if
#         GTOPO30 topography is used (i.e. if the etopo.nc file is used,
#         or 2 if the GEBCO_08.nc topography file is used.
#         The second parameter gives smoothing length, in kilometers.
#         Increasing the smoothing length decreases the number of
#         spurious points in the deposit created by abrupt topography.
#         Smoothing lengths of 30-50 km have yielded reasonable results.
# Line 6: Topofile name. This may be either "etopo.nc" (if GTOPO30
#         topography is used), or GEBCO_08.nc, if using the GEBCO topography
#         database.
***** BLOCK 9 *****
3d_tephra_fall.nc      # Name of output file
St. Helens forecast    # Title of simulation
no comment             # Comment written to NetCDF file
no                     # use topography?
1 40.                  # Topofile format, smoothing length
ETOP01_Ice_c_gmt4.nc   # toptofile name

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