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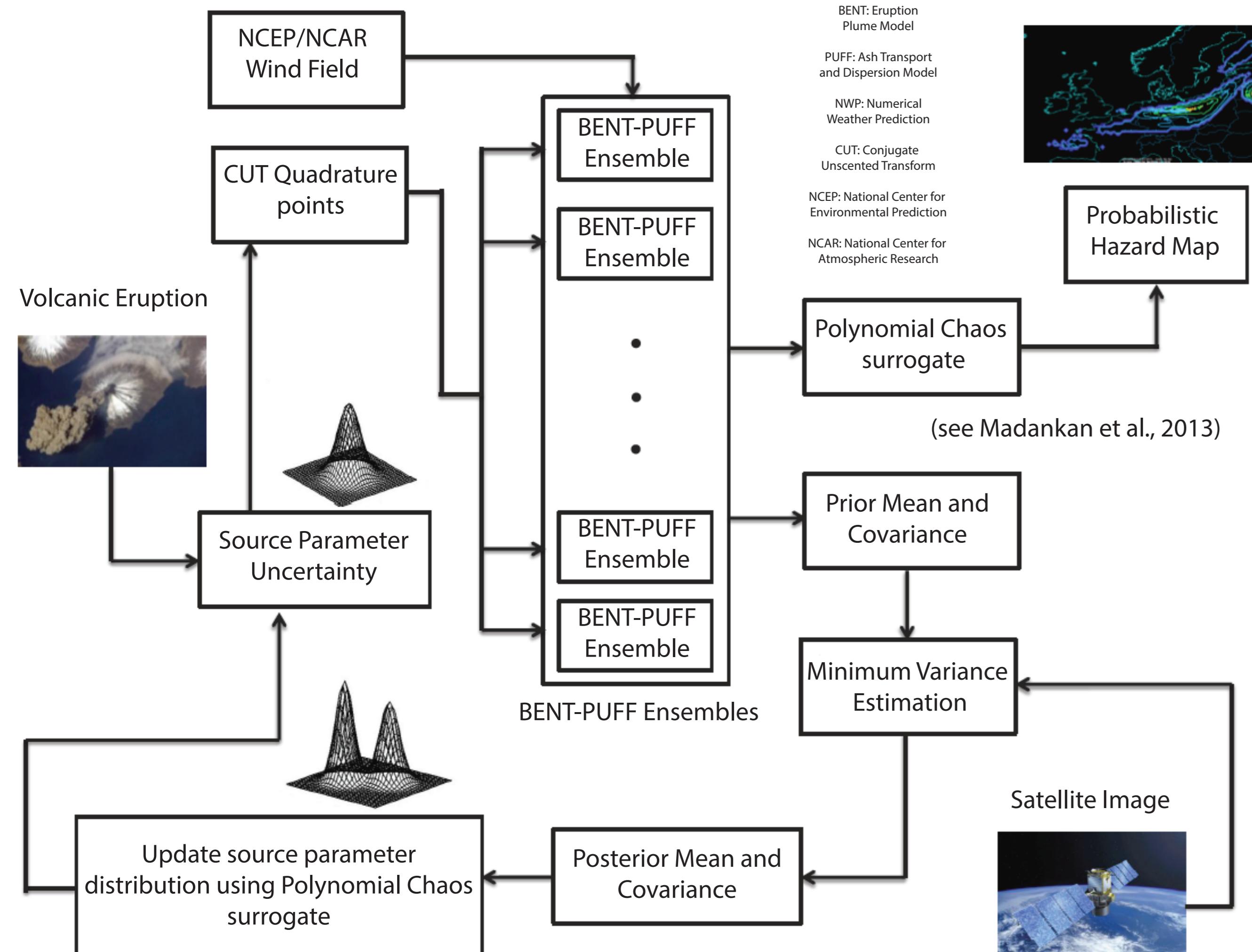
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Introduction/Rationale

Volcanic ash clouds are a significant hazard for the aviation community. Volcanic Ash Advisory Centers produce volcanic ash advisories on the location of ash clouds at +6, +12 and +18 hrs from the timing of the detected event. They use volcanic ash transport and dispersion (VATD) models to provide the forecasted location of the ash clouds. Volcanic events in 2010 & 2011 brought together an international volcanic ash task force to discuss potential improvements to the operational forecasting of volcanic ash.

Given the uncertainties that exist in the modeling inputs and the variability in the atmospheric conditions that can exist during a volcanic eruption, probabilistic ash forecasts from VATD models became a topic of discussion. Here, we present results from a National Science Foundation interdisciplinary research project between SUNY-Buffalo and University of Alaska Fairbanks. See Patra et al. (2013) for more details on the framework for the joint work.

Workflow



- * Novel integration of computational/statistical modeling and volcanic ash dispersion code
- * Quantitative measures of confidence in predictions of the motion of volcanic ash clouds
- * Account for varying wind conditions and a range of model variables
- * Coupled a real-time model for ash dispersal, PUFF, with a volcanic eruption model, BENT
- * Definition of the variability in the dispersal model inputs

- * Classify the uncertainty that can then propagate for the cloud location & concentrations
- * Additionally analyze the uncertainty in the numerical weather prediction forecast data
- * Using ensemble forecasts and assess how this affects the downwind concentrations
- * Provide a quantitative measure of the reliability (i.e. error) of those predictions

Project aim: to provide a probabilistic forecast of location and ash concentration that can be generated in real-time and used in the operational ash cloud hazard assessment environment.

Probabilistic modeling system

Running the Puffin tool

```
VOLCANO NAME: Cleveland
ERUPTION DATE: "2014-12-03 00:00"
PLUME-SHAPE: poison
VENT RADIUS: 37 M
AXIAL VENT-JET VELOCITY: 197.00000 M/S
WATER CONTENT: 1.7000000 WT %
ERUPTION TEMPERATURE: 1200.0000 K
HEIGHT OF VENT ABOVE SEA LEVEL: 1730.0000 M
GRAVITY TO PLUME MAXIMA: -1.0000000 0.0000000
Grain size, mean (phi scale): -8.7400002
Grain size, std dev (phi scale): 1.3400000
ASHOUT:TRUE MODEL: avn
RUNHOURS:24 NASH:1000000 SAVEHOURS:2 ERUPTHOURS:3
ERUPTMAS:5:11
GRIDSIZE:0.05x1000
BENT:5:11
```

BENT inputs

BENT outputs

Puff input commands

puff command line is written to: run.puff

Running the Puff VATD model

```
Reading u from /home/webley/puff_data/avn/2014120300.nc done.
Reading v from /home/webley/puff_data/avn/2014120300.nc done.
Reading Z from /home/webley/puff_data/avn/2014120300.nc done.

Converting levels to geopotential meters ... done.

Making vertical wind ... done.

Volcano: Cleveland ( 190.055, 52.822 )
Start Time: 2014-12-03 00:00 GMT (1417564800)
End Time: 2014-12-04 00:00 GMT (1417651200)

RUNNING:
2014-12-03 00:00:00 GMT
2014-12-03 06:00:00 GMT
2014-12-03 12:00:00 GMT
2014-12-03 18:00:00 GMT
2014-12-04 00:00:00 GMT

Saving Puff output timings

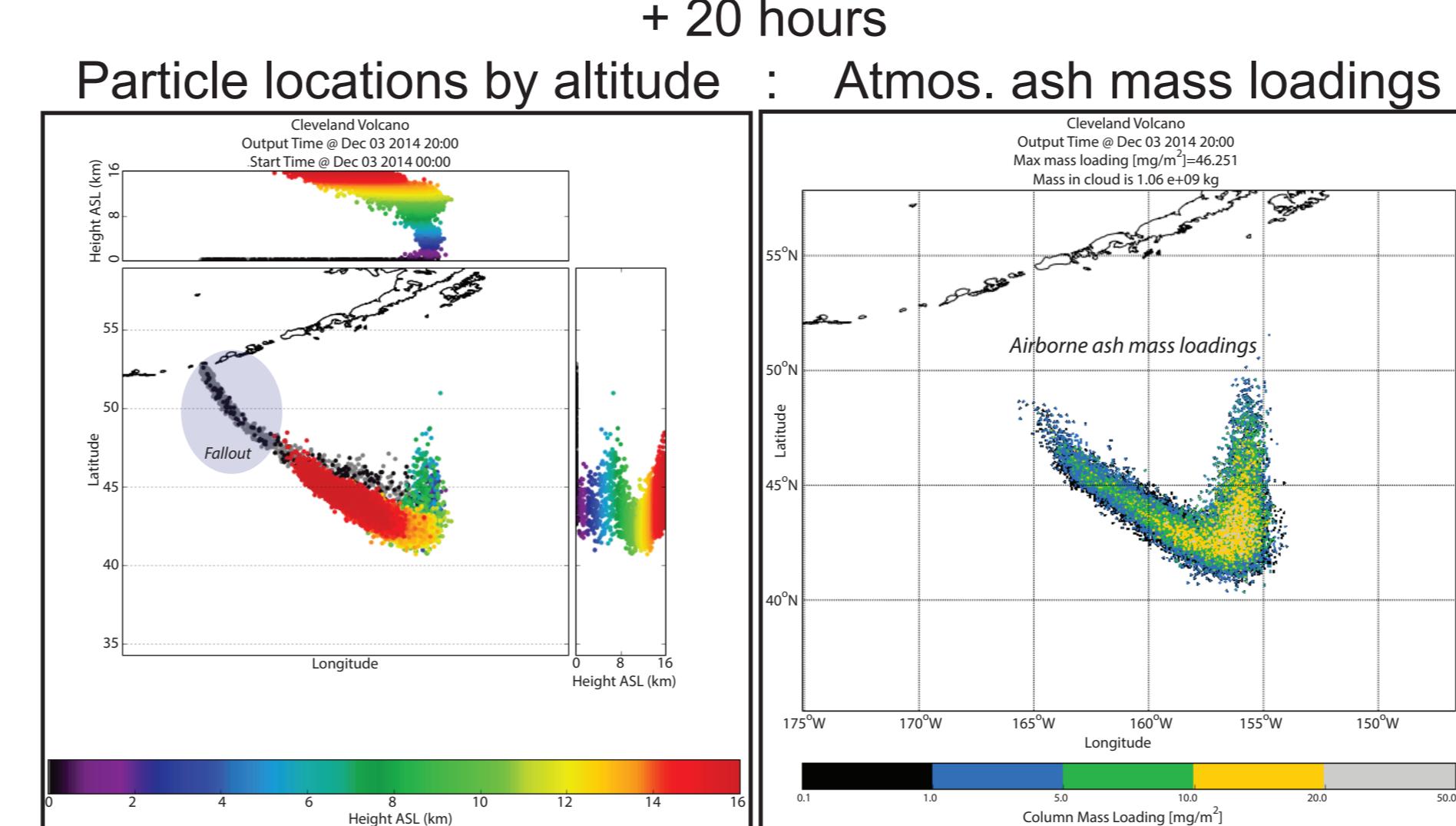
Writing concentration file "/201412030000_conc.nc" ... done.

Timing: 124.59 user 0.24s system 0:13 elapsed 950%CPU
(0avgtext+0avgdata 732464maxresidentjkloutputs+38872outputs
(major+9365minor)pagefaults 0swaps)
```

Cleveland Volcano

Job Number 1

Cleveland Volcano
 Start time: Dec 3, 2014 at 00:00 UTC
 3 hour eruptive event
 Plume Height = 14.6 km ASL
 Mean particle size = 3 μ m
 PSD has 63% from 0.3 μ m to 30 μ m
 Total mass = 5×10^{11} kg
 Very Fine PSD



Add in additional layers to modeling system with NWP ensemble members

Defining the VATD model inputs

1

Determines Start Time and Date
 Grabs local radiosonde at closest time
 Builds Puffin template

2

Defines Input Variability for Set Parameters
 Sets up # of required Puff VATD simulations
 Starts scripts, user can define # in parallel

3

Per Parallel Run

Runs Puffin
 Reads inputs for Puff model
 Builds Puff command line inputs
 Runs Puff Dispersion model
 Output files of particle locations and ash concentrations

4

All jobs completed
 Builds Combined Outputs
 Displays Probabilistic Maps

End program

Extract the radiosonde data

```
http://weather.uwyo.edu/cgi-bin/sounding?region=rp&TYPE=TEXT&LIST=3ALIST&YEAR=2014&MONTH=12&FROM=0300&TO=0300&STNM=70316

Resolving weather.uwyo.edu... 129.72.77.74
Connecting to weather.uwyo.edu[129.72.77.74]:80... connected.
HTTP request sent, awaiting response... 200 OK
Length: 13639 (13K) [text/html]
Saving to: 'sounding?region=rp&TYPE=TEXT&LIST=3ALIST&YEAR=2014&MONTH=12&FROM=0300&TO=0300&STNM=70316'

2014-12-03 14:13:37 (160 KB/s) - &sounding?region=rp&TYPE=TEXT&LIST=3ALIST&YEAR=2014&MONTH=12&FROM=0300&TO=0300&STNM=70316 saved
```

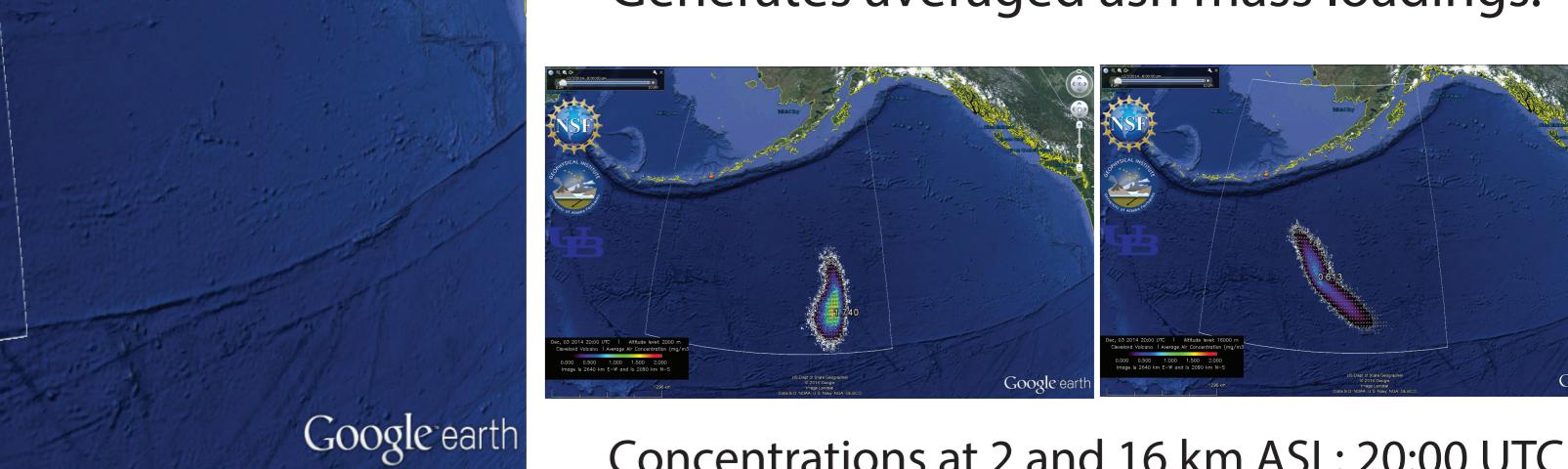
Building combined concentration data

```
Opening found file for processing: d_runs/job160/201412030000_conc.nc
netCDF numdim=4, numvars=10, numglobalatts=3, unlimdimID=0
var IDs: 0, 1, 2, 2, 3=4=4
5=5, 6=6, 7=7, 8=8=9
names: 0-time, 1-lat, 2-long, 3=lon
6=abs_air_conc, 7=abs_fallout_conc, 8=air_size, 9=fallout_size
dim: 0=1, 1=8, 2=lat, 3=lon
var ID: dimIDs: 4 : 1, 2, 3, 0
var ID: dimIDs: 5 : 1, 2, 0
var ID: dimIDs: 6 : 1, 2, 3, 0
var ID: dimIDs: 7 : 1, 2, 0
var ID: dimIDs: 8 : 1, 2, 3, 0
var ID: dimIDs: 9 : 1, 2, 0
dimensions of concentration/data6 = 500 400 8 12
Sum of weights contributing to max height calculation = 0.998960
Size of maxd array = 500 400 12 total 2400000
Size of maxh2 array = 500 400 12 total 2400000
Elapsed time is 1908.11699 seconds.
Time to analyze all 161 Puff output files
```

Dimensions of file X by Y by Z by t

Plotting probabilistic maps of ash concentration

* 4-D probabilities in space and time;
 * Prob. exceeding threshold in atmosphere;
 * Averaged ash mass concentrations;
 * Generates averaged ash mass loadings.



Concentrations at 2 and 16 km ASL: 20:00 UTC

Next steps

- * Streamline the workflow to use one programming language;
- * Further developments in NSF SI2-SSI project: 1339765;
 - [Collaborative Research: Building Sustainable Tools and Collaboration for Volcanic and Related Hazards]
- * Adapt the system to use different VATD models;
- * Build website interface to display the results as derived product;
- * Integrate workflow with observational data;
- * Connect with operational community to discuss application of products for real-time events.

Further Reading

- Bursik, M., et al. "Estimation and propagation of volcanic source parameter uncertainty in an ash transport and dispersal model: application to the Eyjafjallajökull plume of 14–16 April 2010." *Bulletin of Volcanology* 74.10 (2012): 2321–2338.
- Madakan, R., et al. "Computation of Probabilistic Hazard Maps and Source Parameter Estimation For Volcanic Ash Transport and dispersion." *Journal of Computational Physics* (2014), 271, 39–59.
- Patra, A., et al. "Challenges in Developing DDDAS Based Methodology for Volcanic Ash Hazard Analysis—Effect of Numerical Weather Prediction Variability and Parameter Estimation." *Procedia Computer Science* 18 (2013): 1871–1880.
- Stefanescu, E. R., et al. "Temporal, probabilistic mapping of ash clouds using windfield stochastic variability and uncertain eruption source parameters: Example of the 14 April 2010 Eyjafjallajökull eruption." *Journal of Advances in Modeling Earth Systems* (2014), DOI: 10.1002/2014MS00032.