Probabilistic volcanic ash cloud simulations: Characterizing the uncertainty and moving into the operational environment

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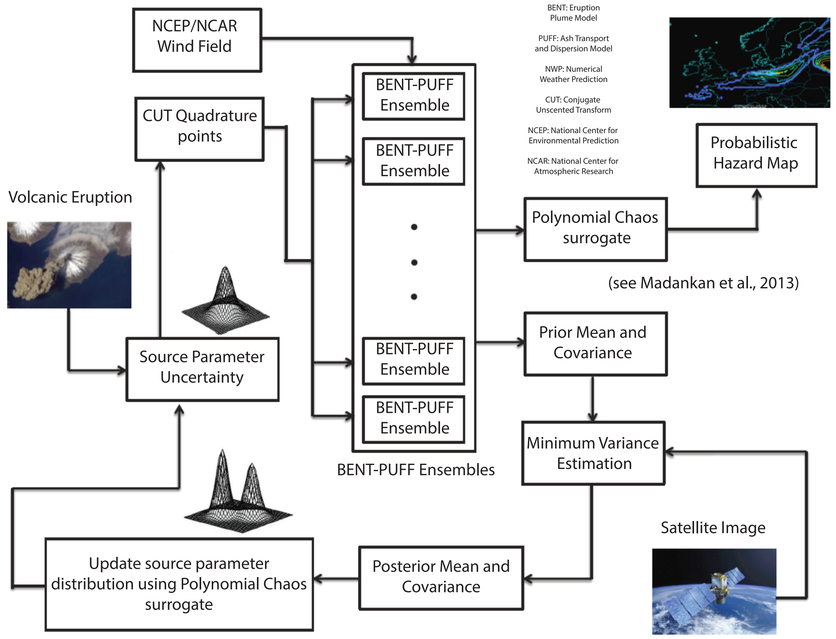
Introduction/Rationale

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

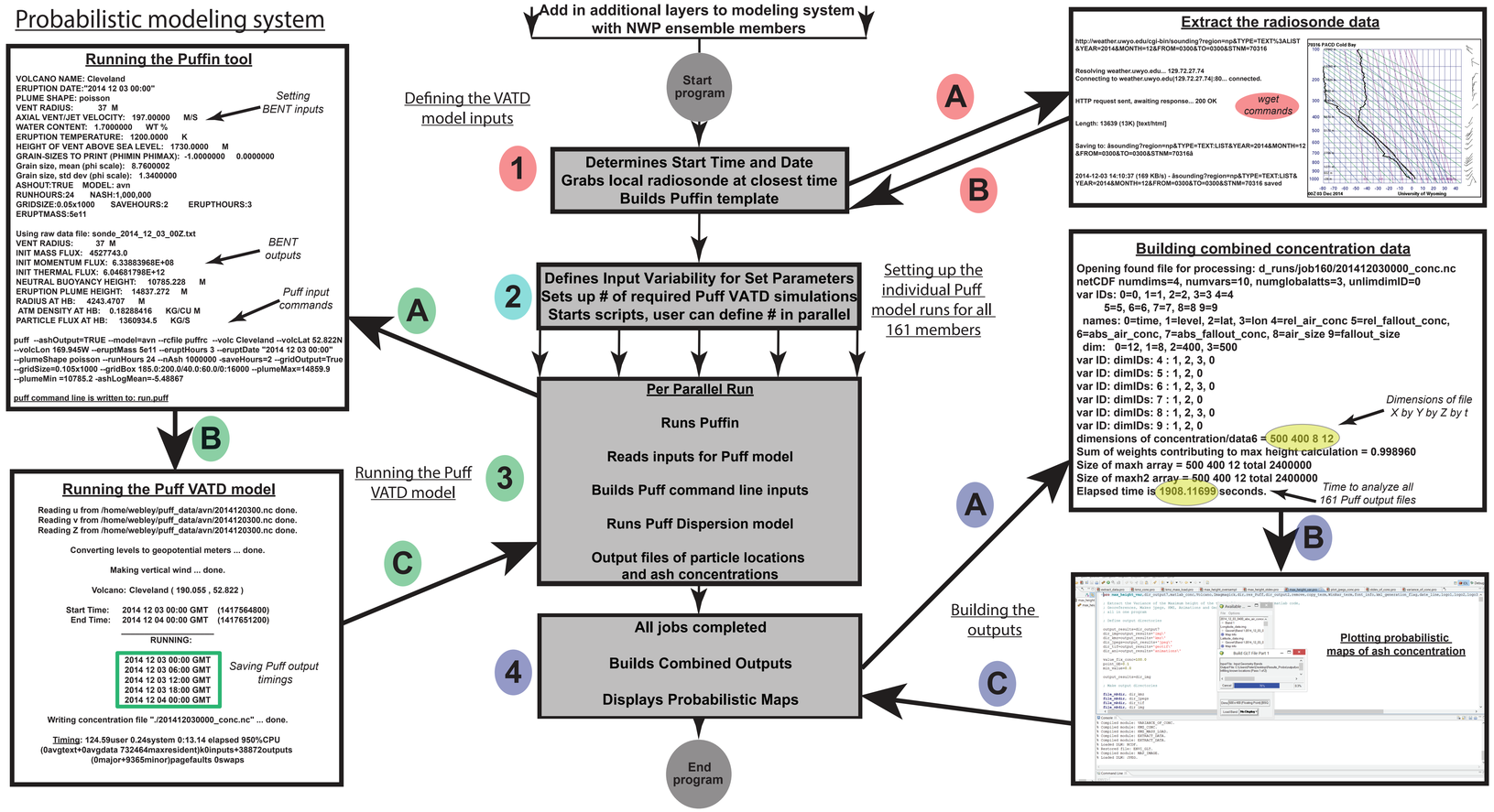


* Novel integration of computational/statistical modeling and volcanic ash dispersion code
* Quantitative measures of confidence in predictions of the motion of volcanic ash clouds
* Account for varying wind conditions and a range of model variables
* Coupled a real-time model for ash dispersal, PUFF,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



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

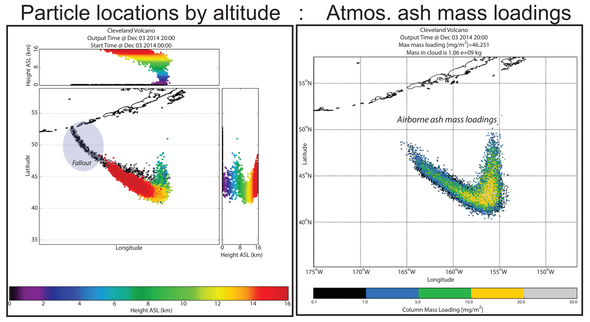
Mean particle size = 3 μm
PSD has 63% from 0.3 μm to 30 μm

Total mass = 5×10^{11} kg

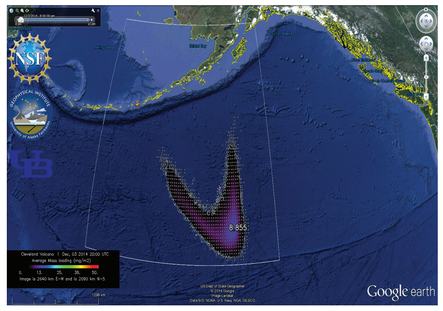
Very Fine PSD

+ 20 hours

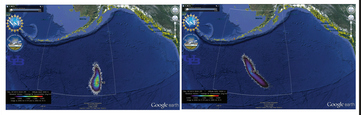
Particle locations by altitude : Atmos. ash mass loadings



Ash Loading Maps for Cleveland Volcano, input variability with 161 members



* 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 Eyjafjal-lajokull plume of 14–16 April 2010." Bulletin of volcanology 74.10 (2012): 2321-2338.

Madankan, 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: 10.1002/2014MS000332.