

Characterization of Eruption Source Parameters and Propagation of Errors in Transport and Dispersal Models

[M. Bursik](#), R. Madankan, S. Pouget, E.R. Stefanescu

M. Jones, A. Patra, B. Pitman, P. Singla, T. Singh, D. Morton

P. Webley, K. Dean, J. Dehn, S. Carn, M. Pavolonis, H. Bjornsson, M. Ripepe

November 2013

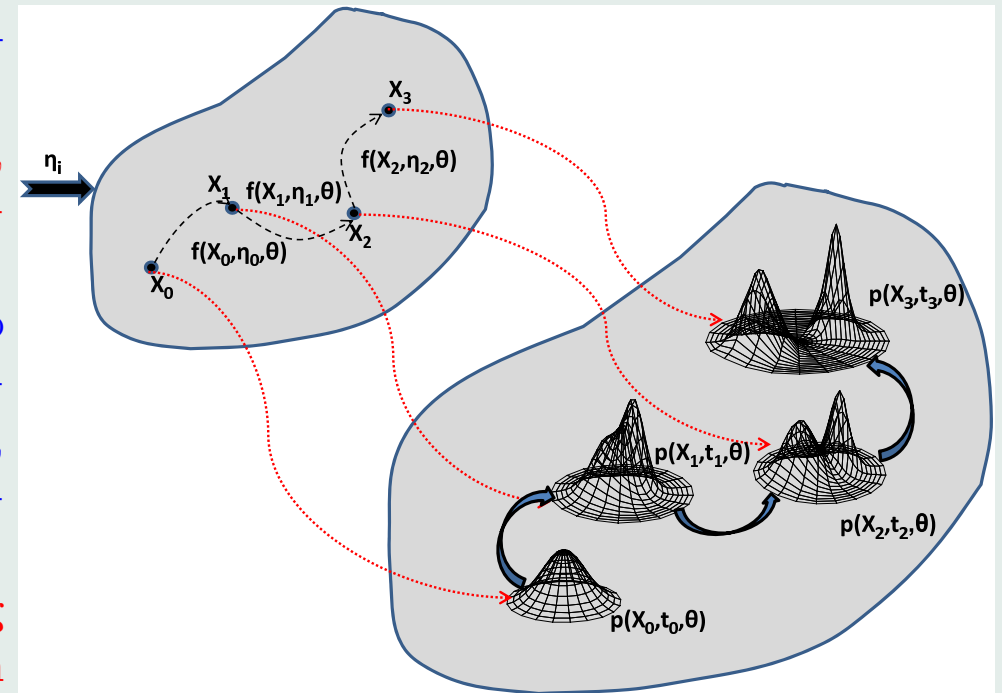
UB — UAF — MTU — NOAA-NESDIS — IMO — UFirenze

National Science Foundation – Air Force Office of Scientific Research

University at Buffalo Center for Geohazards Studies

Introduction

- **Main challenge:** Characterize the system states, and the uncertainty in the system states due to *parametric and input uncertainties* simultaneously
- **Sources of uncertainty:** system parameters, initial conditions (volcano eruption source parameters), input to the system (wind field)
- **Main objective:** develop analytical means to accurately characterize the state probability density function (*pdf*) subject to initial condition, (possibly non-Gaussian) parametric, and input uncertainty
- **Robust characterization and modeling of uncertain variables and propagation of uncertainties is needed to accurately quantify the uncertainty in the solution at any future time**



State and *pdf* transition

Model

Initial Condition: Eruption Source Parameters

Developing techniques to characterize eruption source. In this talk: **Growth rate of umbrella cloud or downwind plume provides accurate measure of mass eruption rate and eruption duration, hence mass loading and concentration?**

Volumetric flux into **umbrella cloud**, \dot{V}_{Hb} , is for quasisteady growth between t_{i-1} and t_i :

$$\dot{V}_{Hb,i} = \frac{2\pi}{3\lambda N} \frac{R_i^3 - R_{i-1}^3}{t_i^2 - t_{i-1}^2} - \frac{2V_{Hb,i-1}(t_i - t_{i-1})}{t_i^2 - t_{i-1}^2} \quad (1)$$

where $V_{Hb,i-1}$ = volume at time $i - 1$, R = radius, and t = time, λ = umbrella shape factor, and N = Brunt-Väisälä (buoyancy) frequency.

Downwind plume spreads in cross-wind direction as gravity current, then by atmospheric dispersion:

$$\dot{V}_{Hbi} = \frac{(w(x_i)u)^2}{2\lambda'Nx_i} \quad (2)$$

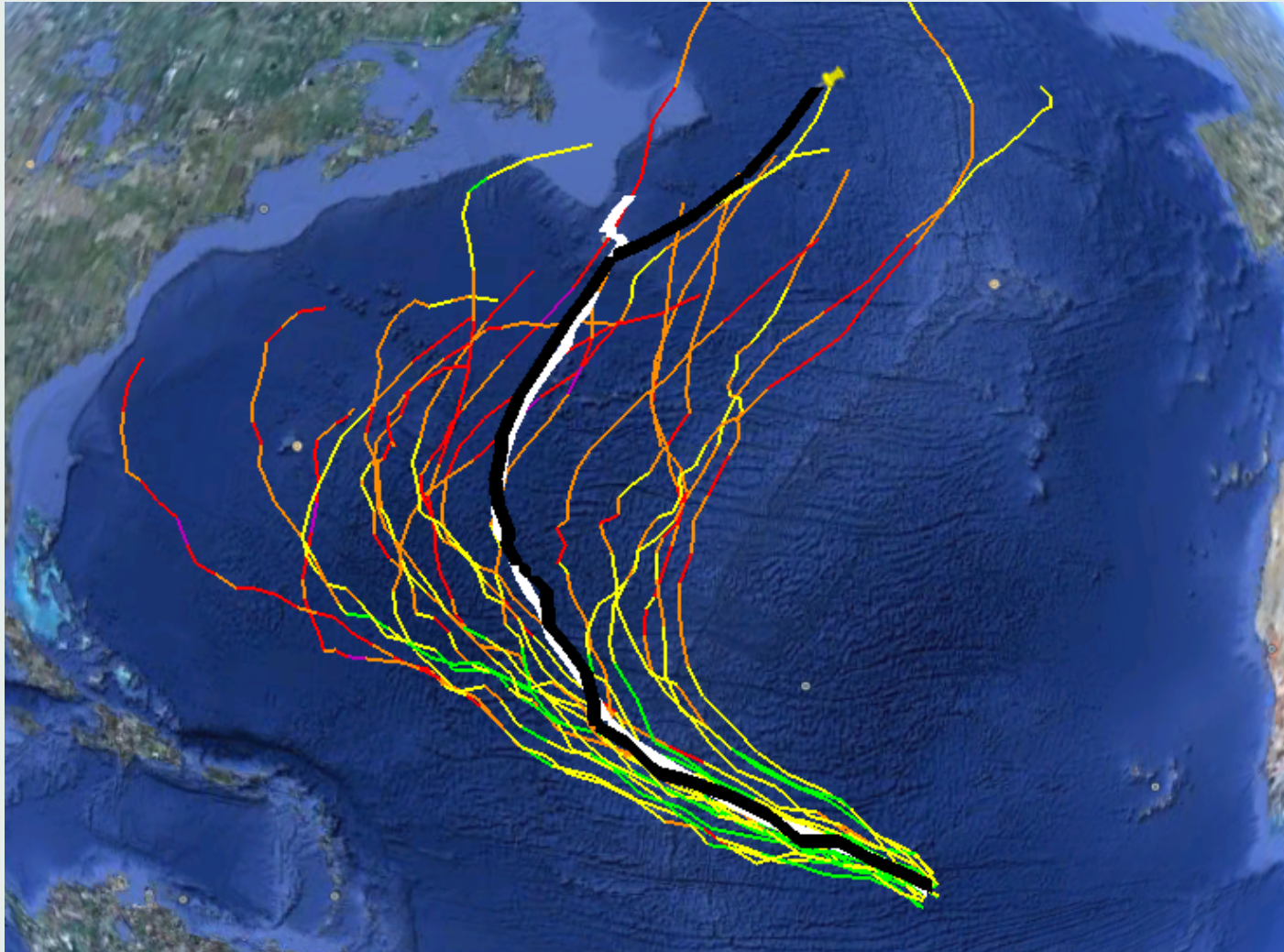
where x_i = downwind distance, $w(x_i)$ = width, λ' = shape factor, and u = wind speed.

To get mass flux of particles, $\dot{m}_{p,Hb}$ from \dot{V}_{Hb} :

$$\dot{m}_{p,Hb} = \dot{V}_{Hb}(\bar{\rho} - P_{\bar{H}}/(R_dT_b)) \quad (3)$$

where $P_{\bar{H}}$ and $\bar{\rho}$ = are pressure and density at intrusion mid-depth from radiosonde, and T_b = satellite brightness temperature.

Wind Field



To characterize wind field uncertainty, we use Weather Research and Forecasting (WRF) \pm stochastic kinetic energy backscatter (SKEB) forecast wind fields with Global Ensemble Forecast System (GEFS) wind field as boundary conditions.

Data



Cordon Caulle eruption, 2011



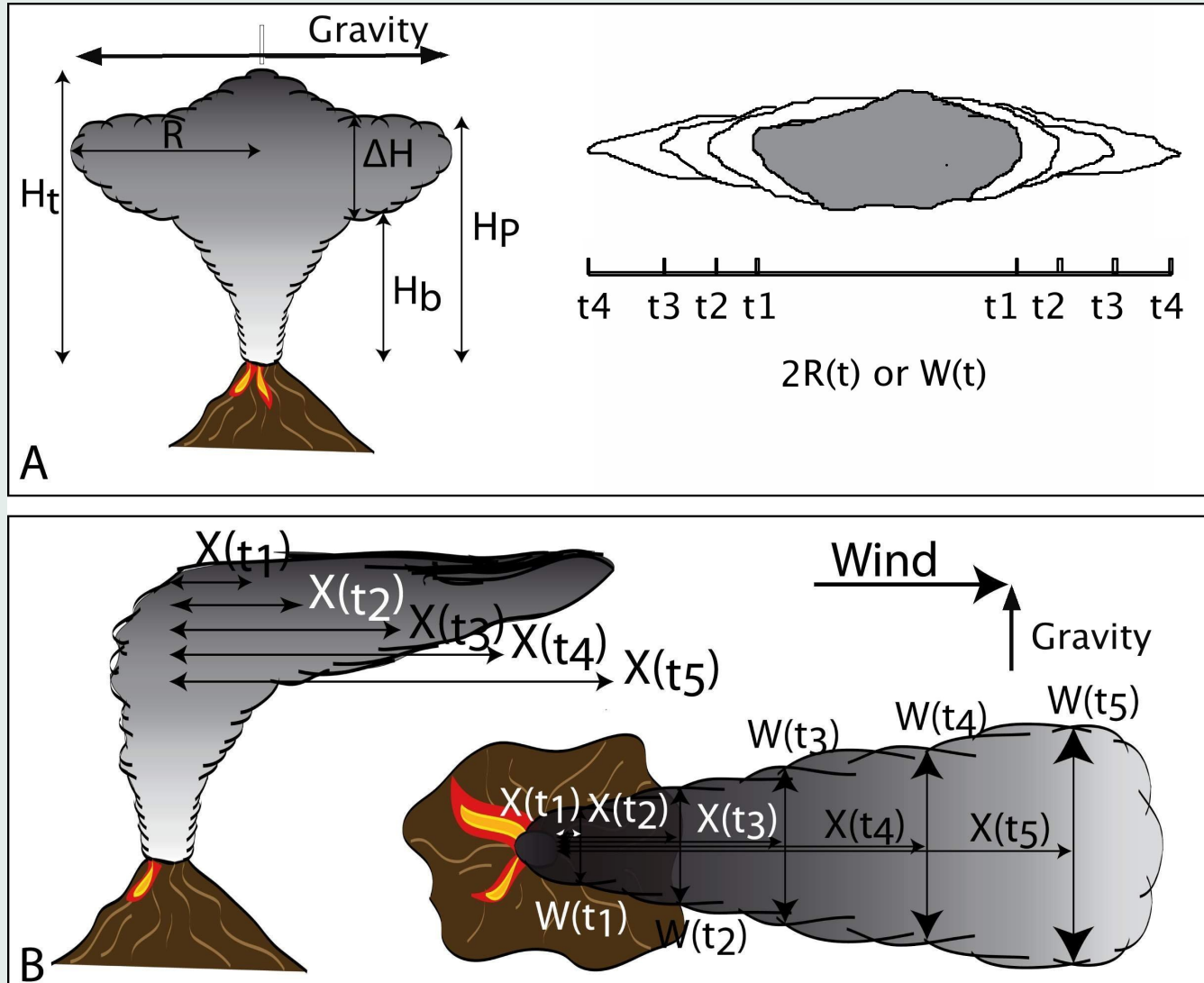
Etna, 14 December 2002 from STS-113.

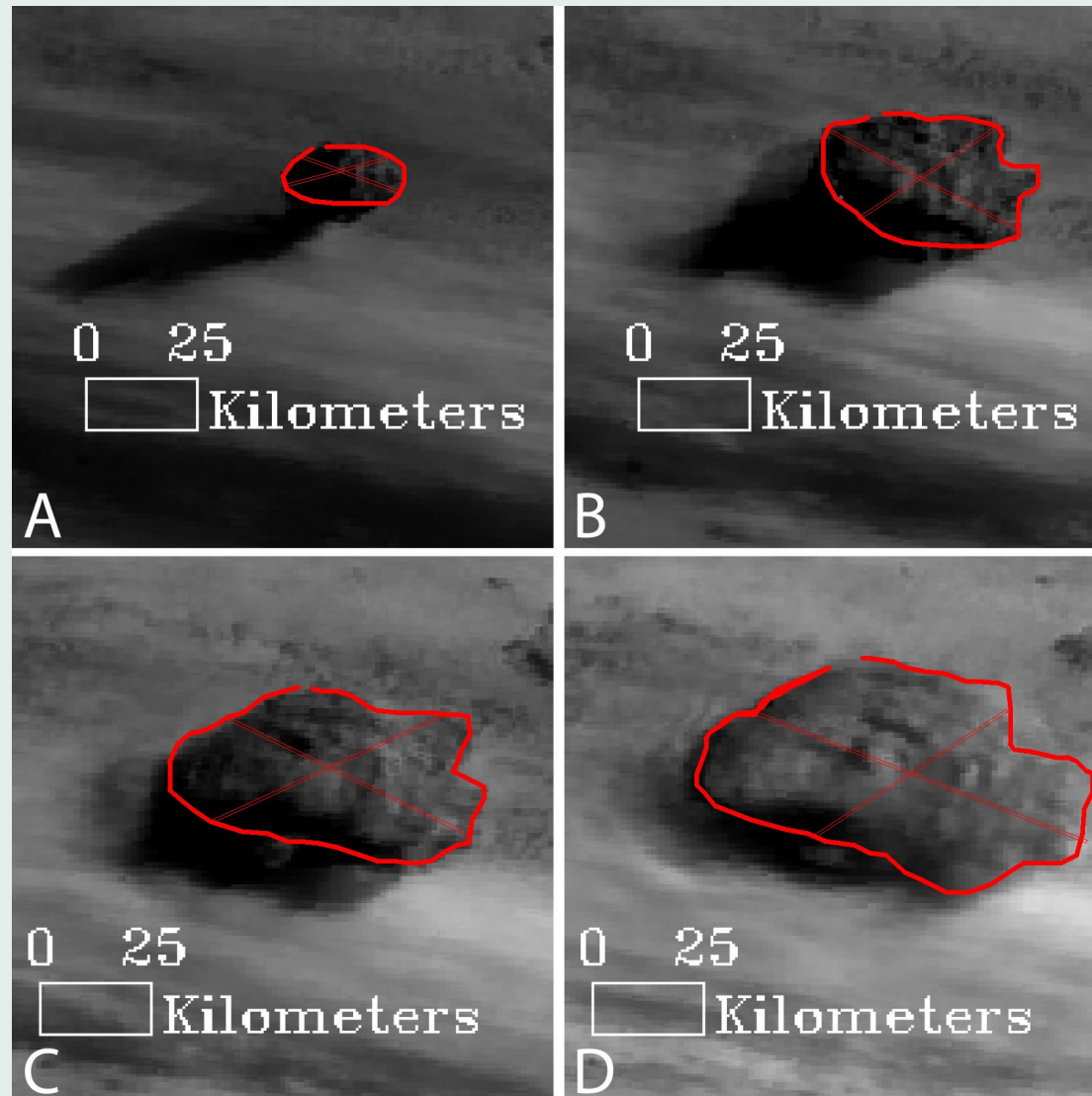


- Upper-level bent over plume
- No flow separation over mountain
- Initially slow, dense eddies drafted downwind – partial wind-driven column collapse
- Low-level gravity current (phoenix cloud) with source S of vent; sharp upwind edge
- Downwind diverging of lower-level and upper-level flow



Methodology



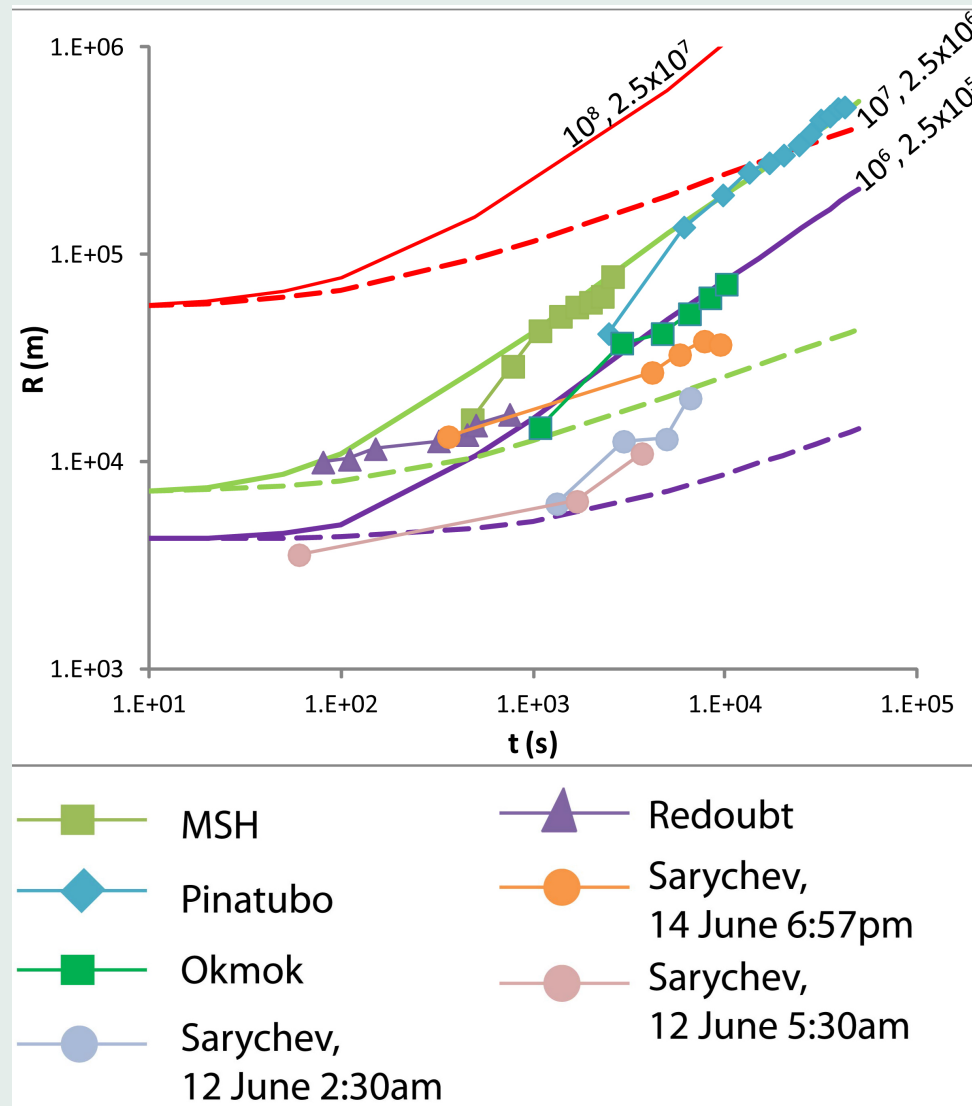


Sarychev Peak **umbrella cloud** of 14 June 2009. (A) 18:57 UTC, (B) 19:30 UTC, (C) 19:57 UTC, (D) 20:30 UTC. Eruption start time 18:51 UTC.

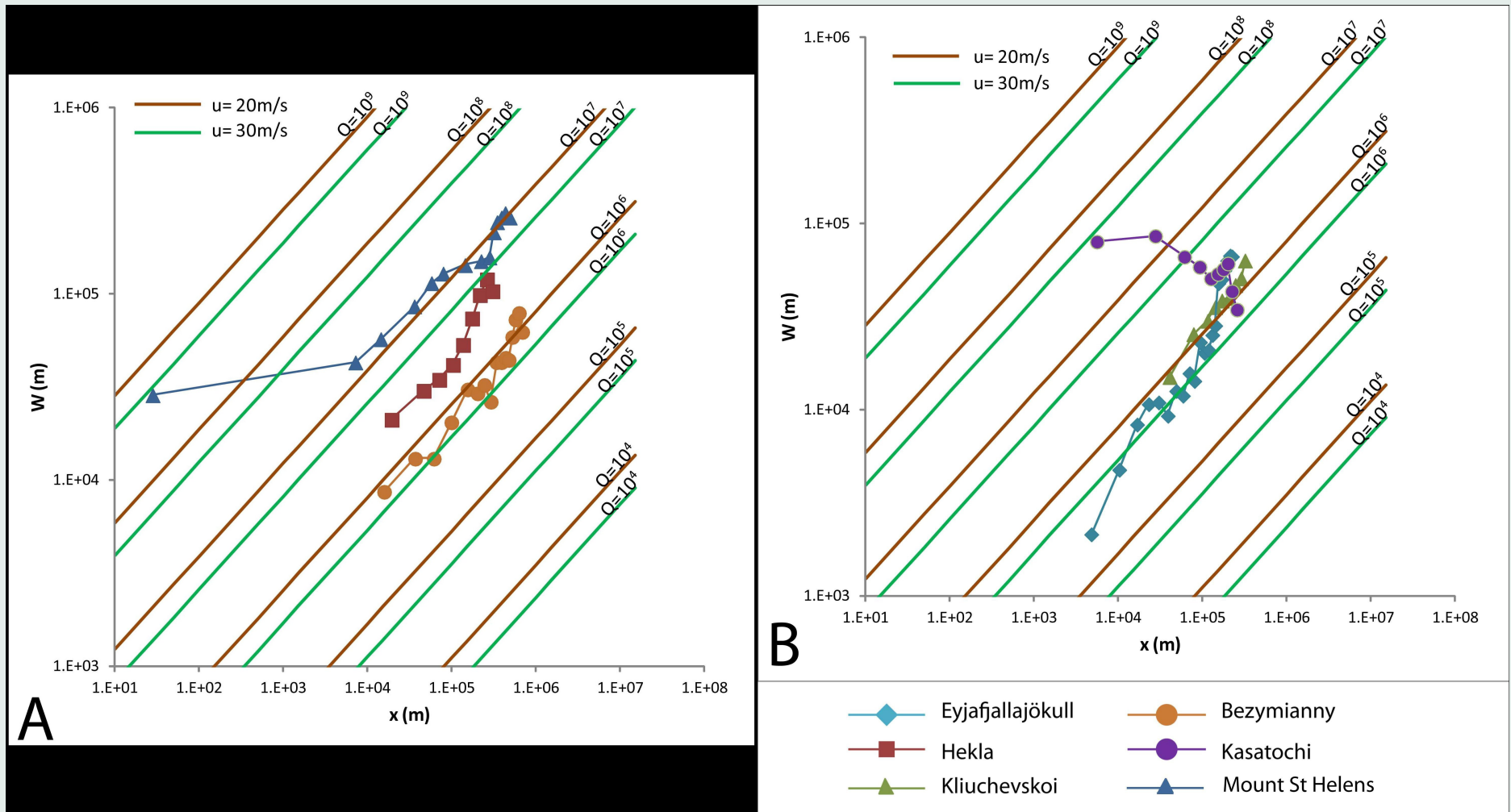


Kliuchevskoi, 1994, STS-068. [downwind plume](#). On satellite images, the width of the plume and the distance from the volcano were measured and backtracked to the volcano for different times of eruption.

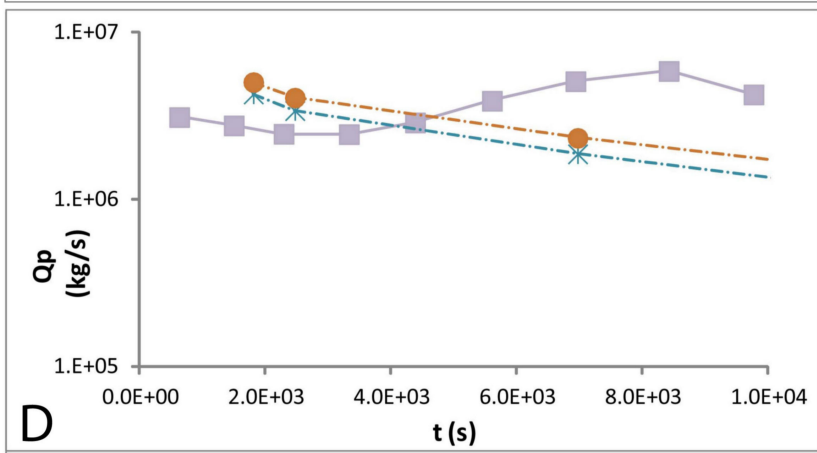
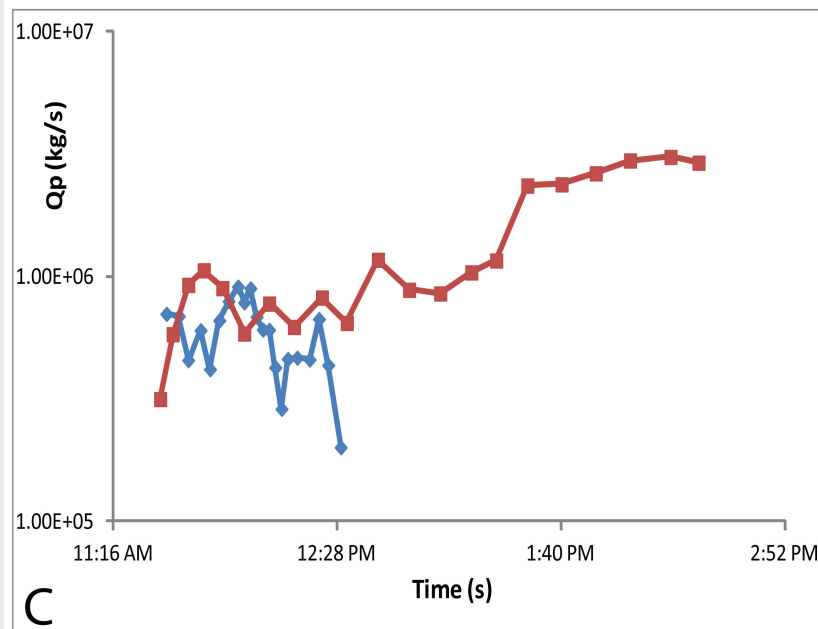
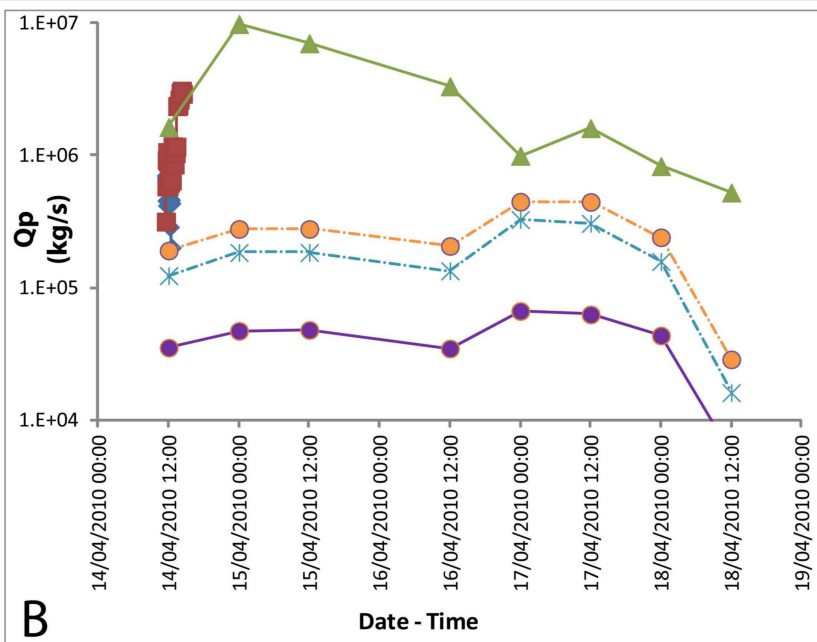
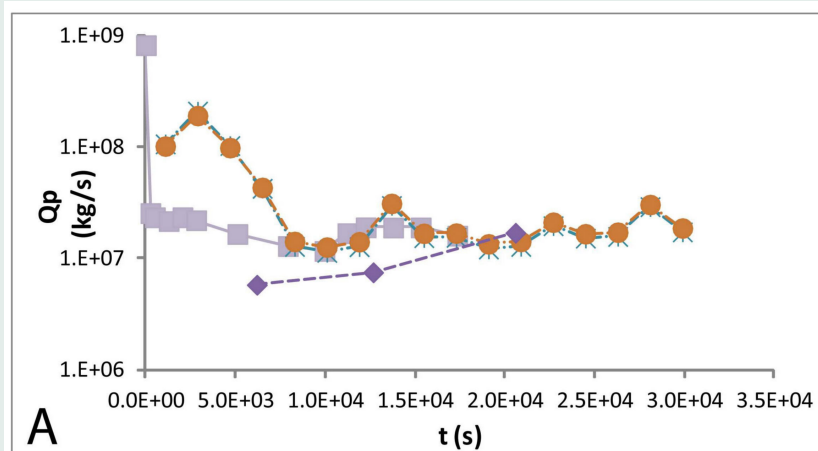
Results and Discussion



Umbrella cloud. maintained (solid line) and instantaneous (dashed line) sources. Numbers next to continuous curves are $\dot{m}_{p,V}$ and $\dot{m}_{p,Hb}$, respectively.



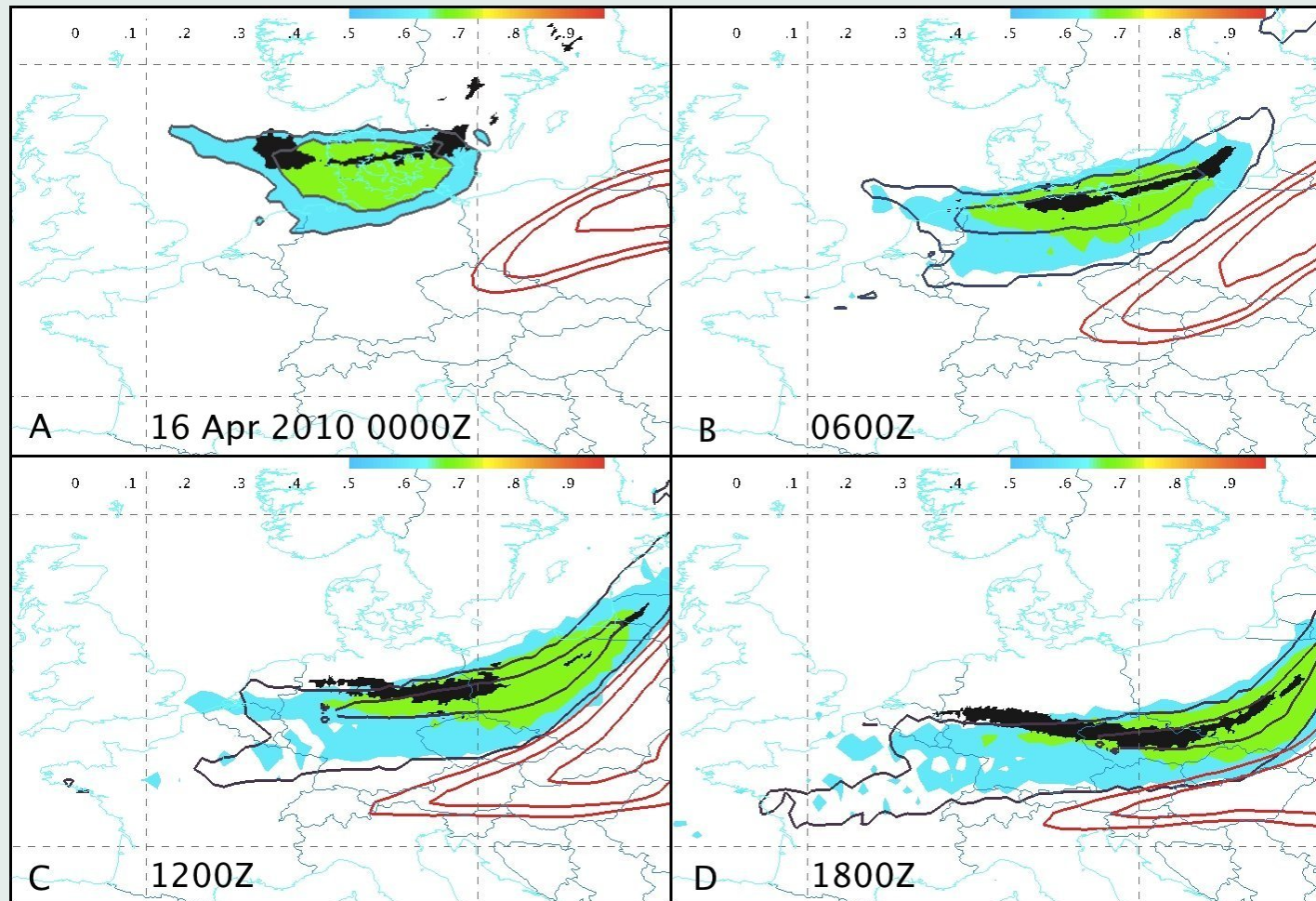
Downwind plume. diamond – Eyjafjallajökull; circle – Kasatochi, 2008; triangle – Kliuchevsko'i, 1994. circle – Bezymianny, 2012; square – Hekla, 2000; triangle – Mount St Helens.



Different estimates of mass eruption rate. A) Mount St. Helens, 1980. B) Eyjafjallajökull, 2010. C) Expansion of (B). D) Hekla, 2000.

Outputs

1. Estimates of mass loading and concentration directly from output, e.g., Pinatubo $\sim 5 \times 10^{12-13}$. Initial concentration all eruptions ranges from several to $\sim 100 \text{ g/cm}^3$.



2. **Probability of ash presence** for Eyjafjallajökull, April 16, 2010. Black, SEVIRI ash; colored region, only ESP uncertainty; gray line, forecast starting April 16, 2010 0000Z; red line, forecast starting April 14, 2010 0000Z.

Conclusions and Future Directions

- Exploring estimation of uncertain source parameters by a variety of methods based on available ground-based, seismic, sounding and satellite data (Bursik et al., 2012, BV)
- **In this contribution, we focused on estimate of uncertain source parameters from cloud growth rate (Pouget et al., 2013, JVGR)**
- Given these and uncertain wind fields, we have ...
- Created probabilistic forecast of ash position at 0, 6, 12, 18 hr and 60 hr after beginning of eruption using uncertain eruption source parameters, and WRF-GEFS, multi-model and SKEB ensembles (Stefanescu et al., in review, JAMES)
- Source parameter inversion, data fusion, fast surrogate model (emulator) construction (Madankan et al., in press, JCP), multi-model VATDM, hole filling
- Building system in an (offline) operational setting at UAF (AGU posters PA21B-1877 and V23B-2812)
- Working with U. Bristol group on comparing data with improved physics model (AGU poster V23C-2861) and BOM group on use of automated algorithm to measure and estimate growth rates (AGU talk)