

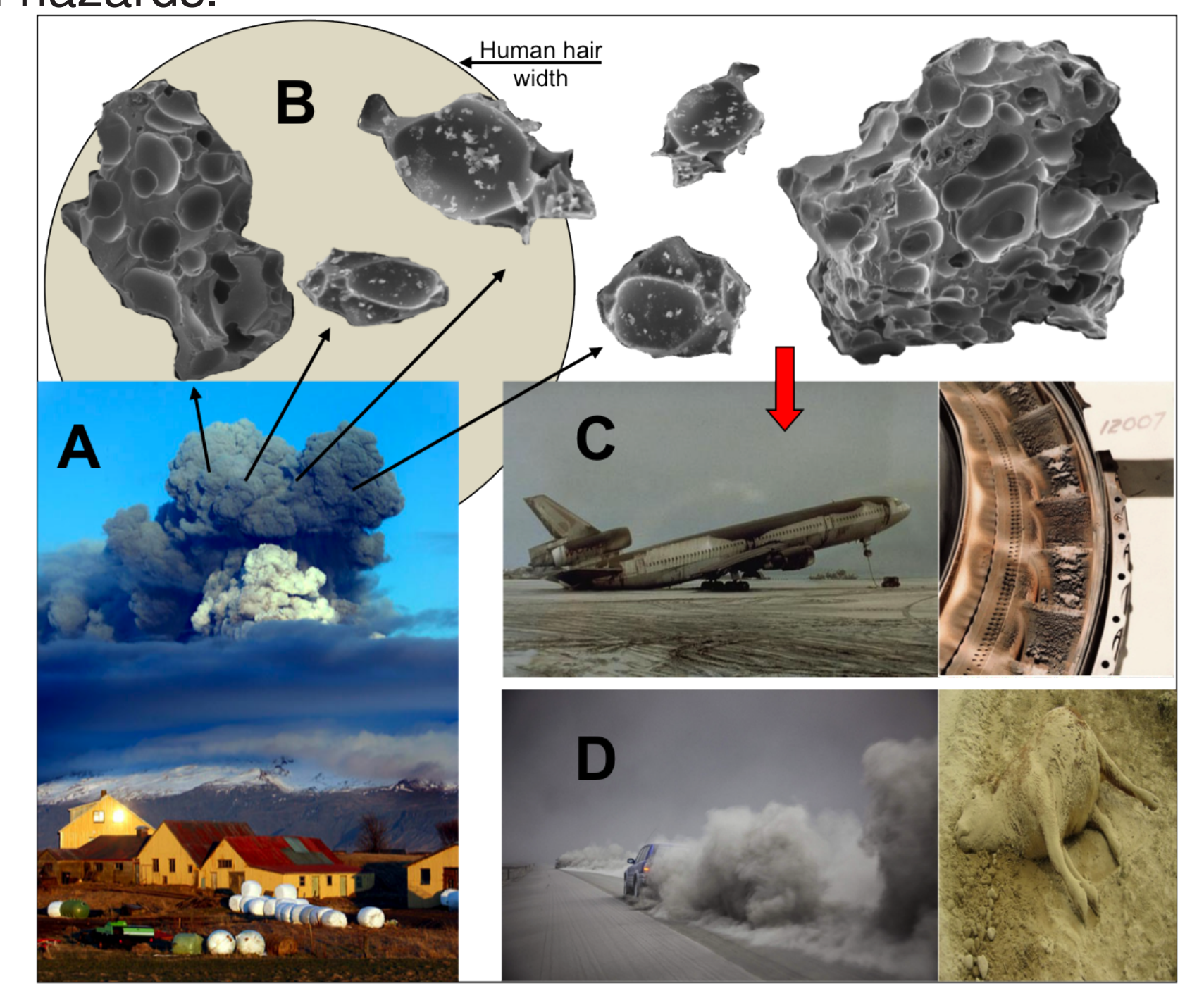
# ATMOSPHERIC FATE AND TRANSPORT OF FINE VOLCANIC ASH: DOES PARTICLE SHAPE MATTER? V23C-2866



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## PROBLEM

Volcanic ash presents hazards to infrastructure, agriculture, and human and animal health. Predicting the fate and transport of airborne ash is of great practical importance to mitigate such hazards.



- (A) Eruption of Eyjafjallajokull (Iceland) in 2010.
- (B) SEM particles of ash particles.
- (C) Impact of ash on aircraft and jet engine.
- (D) Images of ash fallout and impact on livestock.

## HYPOTHESIS

The fundamental hypothesis being tested is that particle shape irreducibly impacts the fate and transport properties of fine volcanic ash.

- The time fine ash stays in the atmosphere depends on its terminal velocity.
- Existing models of ash terminal velocities are based on smooth, quasi-spherical particles characterized by Stokes' law.
- Ash particles violate many assumptions of Stokes' law, in particular, ash particles are non-spherical and can have complex surface and internal structure (see figure (B) above).
- Existing models fail to accurately predict removal rates of fine particles from volcanic ash clouds.

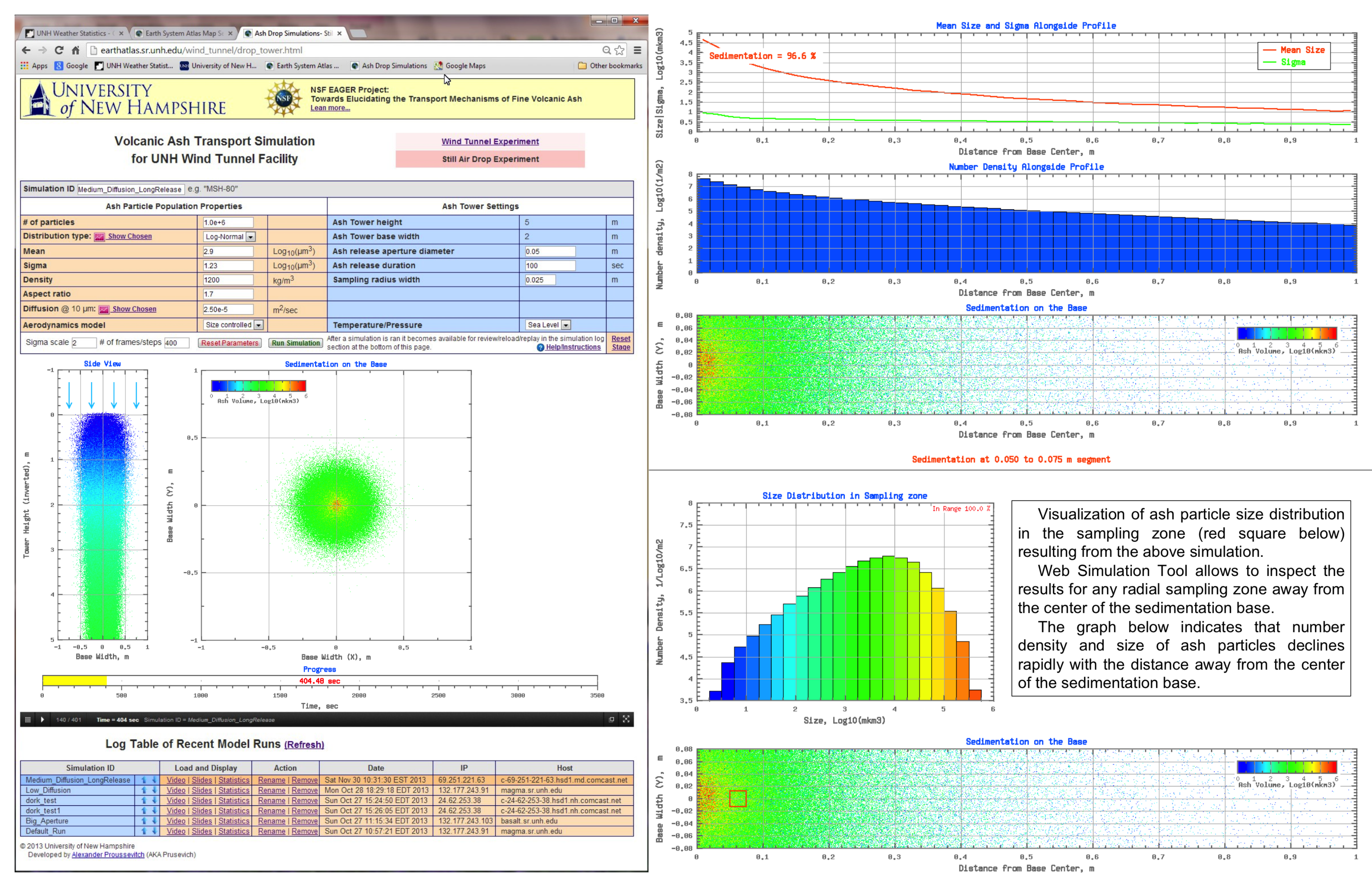
## BROAD OBJECTIVE

The present research seeks to better parameterize predictive models for ash particle terminal velocities, diffusivity, and dispersion in the atmospheric boundary layer that includes the effects of volcanic ash size distributions, complex ash particle geometry, and geometry variability.

## ACKNOWLEDGEMENTS

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## NUMERICAL RESULTS



## MODEL DESCRIPTION

A numerical model for ash transport, dispersion and sedimentation has been developed.

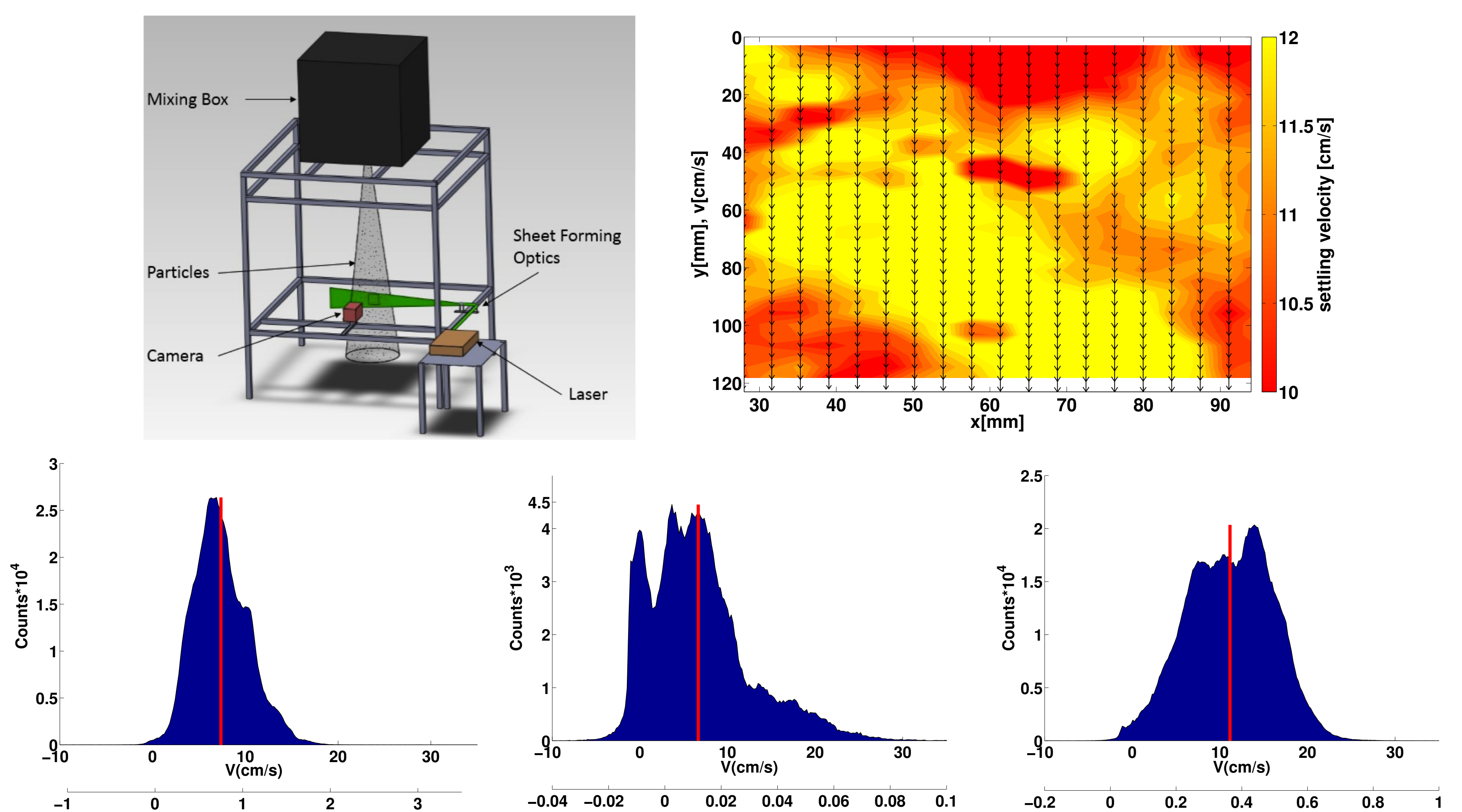
- Web based user interface, visualization and analysis tools that allows for inverse problem solving.
- The goal is to imbed first principle based models informed by experiments to capture the effects of particle shape in the numerical simulation.
- Source code and compiled executables are available at: [http://earthatlas.sr.unh.edu/wind\\_tunnel/drop\\_tower.html](http://earthatlas.sr.unh.edu/wind_tunnel/drop_tower.html)

## EXPERIMENTAL STUDIES

Experiments are being conducted at the Flow Physics Facility (FPF) at the University of New Hampshire.

- Still air drop experiments conducted to determine particle settling velocities and dispersion as a function of particle size and shape.
- Particle size and shape characterized by scanning electron microscope (SEM) studies.
- Particle image velocimetry (PIV) used to acquire planar fields of ash velocity as the ash falls from a 3m drop tower.
- PIV vector plots analyzed to determine particle settling velocity and dispersion

## EXPERIMENTAL RESULTS



Top: (left) Still air experimental setup. (right) Averaged PIV vector plot of ash settling velocities. Bottom: Histograms of settling velocity (left)  $Al_2O_3$  sphere  $\approx 30\mu m$ , (middle) glitter flakes  $\approx 300\mu m$ , (right) volcanic ash  $< 65\mu m$ . The red vertical line denotes the mean and the lower axis is  $V/V_{stokes}$ , where  $V_{stokes}$  is calculated for the particle mean diameter.

## SUMMARY

- Measured settling velocity of  $Al_2O_3$  spheres consistent with Stokes' law  $\rightarrow$  Validates experimental setup.
- Measured settling velocity of ash not consistent with Stokes' law (requires further studies to deconvolve effects of particle size and density distribution from shape effects).
- Estimated diffusion coefficients,  $D(cm^2/s)$ , of the particles:  $Al_2O_3 = 0.99$ , Ash = 3.66, Flakes = 5.81, where

$$D = \sqrt{\frac{u_{rms}^2 L}{v_t}}, \quad (1)$$

- $u_{rms}$  is the root-mean-square of the lateral (horizontal) velocity fluctuations,  $L$  is the height the PIV measurements were acquired below the drop tower, and  $v_t$  is the particle terminal velocity.
- Diffusion coefficient of flakes is largest (as expected).
- Diffusion coefficient of volcanic ash falls between spheres and flakes, suggesting that the shape of volcanic ash strongly affects diffusion.
- PIV vector fields of volcanic ash suggests that ash may be strongly affected by secondary flows induced by initial falling plume. The  $Al_2O_3$  spheres did not exhibit the same behavior. This suggests a possible shape effect that requires additional study.