Transitional dynamics in pyroclastic density currents: Integrating multi-scale observations with macroscopic models of explosive volcanic activity, Josef Dufek, University of California, Berkeley and Georgia Institute of Technology, dufek@berkeley.edu

Explosive volcanic eruptions are some of the most energetic granular flows on the planet, the largest of which can have global impact. The more common, smaller, events are a proximal hazard and still encompass scales of several kilometers. However, mass and energy transfer in all these flows are fundamentally controlled by processes at much smaller spatial and temporal scales, where individual particles interact with each other, with gas, or with the surface over which the flows travel. Our ability to predict large-scale behavior of volcanic flows can ultimately be limited by our understanding of very small-scale, or microphysical, processes. Understanding the role of small-scale processes also yields insight into the timing and location of transitional dense-dilute flows [*Dufek and Bergantz*, 2007b].

During this talk I will discuss how experiments, numerical models, and field observations can be used in concert to discern the dynamics of explosive volcanic eruptions at many different spatial and temporal scales. This information will be used to explore eruptive dynamics of very large events (Kos Platuea Tuff) and examine the dynamics of smaller contemporary events at Montserrat. I will discuss the connection between turbulent and particle-induced sorting in eruptive flows and the information content that can be preserved in their deposits. Linking the deposits with flow conditions from large scale numerical simulations constrains events that are by their very nature difficult to impossible to observe in detail, and gives insight into the dominant energy transfer mechanisms.

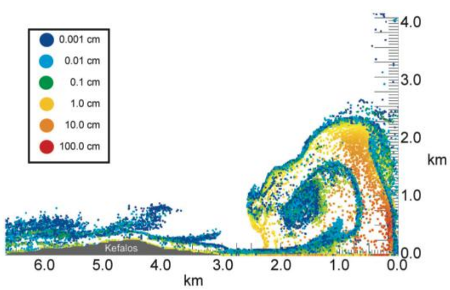

Figure 1: *Eulerian-Eulerian-Lagrangian (EEL) simulation over complex topography. Shown here is the Lagrangian field with larger particles in warm colors and smaller particles with cool colors. Flow is moving from right (collapsing column) to left over pre-existing domes. Note that the particles are being sorted in different regimes of the flow.*

Eruption Dynamics of Voluminous Explosive Eruptions: Insight from the Kos Plateau Tuff

We utilize the natural boundary conditions encountered by the eruption of the Kos Plateau Tuff to probe its internal structure, as well as constrain the neo-tectonic activity in the region and eruption duration of this moderate to large (>60 km^3) event. At the time of the eruption, 161 kyr, the lower sea-level in the Mediterranean may have resulted in flows that traversed mostly land to the north of the eruptive vent, while flows to the south may have encountered an expanse of water. Steep topography and over-water transport can impede the transport of the dense basal portions of the flow, or bed-load, where particles make multiple or sustained contact with the bed. We use an Eulerian-Eulerian-Lagrangian computational approach coupled with over-water and over-land boundary conditions, including topography, to determine the role of bed-load versus suspended load in the transport of these flows. We find that a ring-vent structure and eruptive fluxes greater than $\sim 2\times 10^6$ m^3/s are required for the spatial distribution of the KPT. The maximum grain size and deposit locations of the first voluminous ignimbrite unit (D) can be explained by suspended flow to the south, consistent with over-water transport, and bed-load and suspended load transport to the north, consistent with over-land transport. However, the maximum lithic size for the largest and last ignimbrite unit (E) requires some bed-load transport in all directions. We propose that the boundary conditions were significantly altered during the course of the eruption, either through the in-filling of a shallow sea to the south or the development of a thick pumice raft to aid saltation. Based on the inferred eruptive flux, we estimate that the duration of the eruption climax, in which most of the material was erupted, likely only lasted from a few hours to a day.

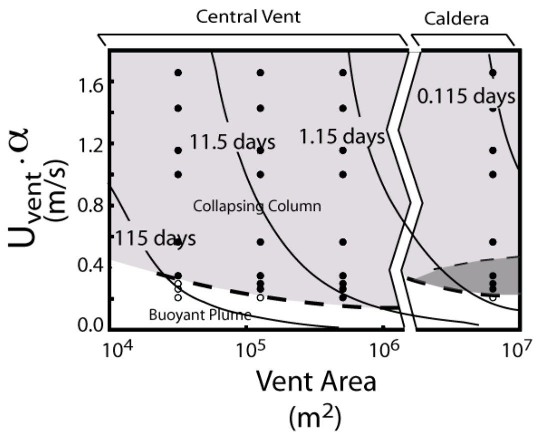

Figure 2. *Regime diagram for eruptive conditions with lines of constant duration of eruption. The estimated eruption duration times were calculated with using the volume of the deposits 60 km^3. Simulated flows that had the range of KPT deposits (dark shaded region) imply minimum eruption duration of 0.35 to ~1.4 days [Dufek and Bergantz, 2007a].*

Heat transfer at small scales: The July 12-13 Montserrat Dome Collapse

Steam explosions, or littoral blasts, generated when pyroclastic flows interact with seawater may be a common, although rarely documented, phenomena. The development of steam explosions rather than passive steam production is related to the rate of thermal energy transfer from hot pyroclasts to water. We conduct a series of laboratory experiments to quantify the heat transfer and steam production rates when hot pyroclasts encounter water [*Dufek, et al.*, 2007]. Hot pumice (> 200 C) rapidly ingests water while remaining at the surface, producing measurable amounts of steam during the process. Approximately 10 % of the thermal energy of the pumice particles is partitioned into the production of steam, and smaller particles have greater steam production rates.

The laboratory experiments are used to develop a subgrid model for steam production that can be incorporated into a multiphase numerical framework. We use this model to study the critical steam production rates required to initiate explosive events. For conditions typical of many pyroclastic flows, particles smaller than ~ 1 - 5 mm are required to initiate a littoral blast. A second set of 2-D numerical simulations is conducted to simulate the July 12-13 Soufriére Hills dome collapse event that reached the sea. The simulations predict that the focus of the blast is likely generated several hundred meters off-shore and although the landward directed base surge is primarily dry (< 15% water vapor), the area immediately above the blast is steam-rich and may be a likely site for the production of accretionary lapilli.

References:

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