IAVCEI Commission on Explosive Volcanism Workshop

Advances in studies of volcanic plumes and pyroclastic density currents

organized jointly by
the ***Laboratoire Magmas et Volcans, Clermont-Ferrand***
and
the ***International Association of Volcanology and Chemistry of the Earth's Interior***

Clermont-Ferrand, France, 26-29 October 2009

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General discussion (1)

Crucial parameters needed by observatories during crises :

- **Timing, magnitude and style (class) of eruption** (e.g. highly explosive / mild strombolian, height of ash cloud)
- **Near-real-time information:** main parameters controlling eruption volume and intensity, and transitions in style/regime (e.g., chamber pressure, ascent rate, fragmentation level, water content)
- **Volcanic products:** height of ash clouds, extent and amount of ashfall, runout of pyroclastic density currents (PDC) and debris flows
- **Communication tools:** need for user-friendly software to simulate eruption processes, evaluate hazards and communicate quickly to authorities/public

General discussion (2)

Inputs from observatories:

- **Before eruption**

  Acquisition of accurate DEM, geological data on eruption history, installation of relevant instrumentation

- **During eruption**

  Satellite information in addition to field observations and 3D meteo data: documentation of evolution of volcanic activity (include pulses & transitions), seismic signatures, PDC velocities, temperatures + info from infrasounds, IR, UV sensors (SO_2 flux) when available

- **After eruption**

  Collect field parameters before erosion/burial: dimensions, volume, extension, stratigraphy, granulometry, morphology

General discussion (3)

Link models and measurables

- **Modellers should continue to define/state parameters that are important to constrain, either in the lab or in the field.**

  - e.g. **particle size distribution in plumes and PDCs** → clues from FLIR camera + Doppler radar combination, LIDAR, hyperspectral / multiple radars, FTIR spectroscopy.
  - e.g. importance of local vs. at source **particle concentration** for column collapse regime

- **Constitutive equations:** more to learn from analogue modelling and scaling analyses

- **Need to couple geophysical and field observations** on targeted field sites

Volcanic Plumes

Plume Deposits

- **More systematic tephrostratigraphic field datasets needed to feed into models.** Gather data on more eruptions, particularly those with geophysical observations

- **Need of better statement of what deposit field parameters should be measured.** Concentrate on what would help improve data available to modellers to align ground-based and airborne field data campaigns

- **Importance of field sampling method:** different sampling can give very different VEIs → perhaps we need a stated protocol for field sampling (e.g., minimum number of sample points, how to make the measurement …)

- **Fine ash anomalies in deposits:** can we gather field parameters to distinguish rain flushing and ash elutriated from PDC?

Plume models

- **Critical influence of time-dependent conduit/crater geometry** (erosion by flow, gravitational wall collapse) on eruption dynamics: how to quantify changes? (cf. ambiguity on the origin of lithics)

- **Importance of ejecta recycling in crater on jet dynamics and morphology of deposits:** need for measurements

- **Gas-particle interactions:** effect of background flow field on ballistics, gas dragging by particles motion; how to measure swirling strength; heat transfer depends on particle shape and temperature/proportion of lithics/ juveniles/gas

- **Combining different ash dispersal models gives better accuracy of outputs** (plume height, volume, mass discharge rate, total mass)

- **More work needed on weak plumes** (entrainment of air) **and unsteady plumes, as these are most common and also pose a hazard**

Remote sensing

- Both **ground-based and satellite-based remote sensing measurements** are converging on variables and parameters that can be estimated from models: need to identify clearly those parameters each technique can measure/infer, and identify those techniques which naturally combine (e.g., Doppler radar and thermal camera)

- **More collection of ground and satellite data of volcanic plumes to calibrate techniques and validate volcanological parameters** (gas mass, air entrainment, mass of magma erupted, grain size, particle concentration etc…)

- **Not enough geophysical data or synchronous datasets on large eruptions** → be prepared to deploy rapidly and in unison to fill this gap

- **More time series coupled with classical monitoring techniques to assess activity variability and identify precursors to transitions**

- **How to merge numerous satellite results?** Opportunities with Global remote sensing network (NOVAC) → better baseline information for continued monitoring efforts: importance for climate issues

Eruption dynamics

- **Need same terminology for field observations and remote sensing**…

Do we need a new classification scheme for eruption styles to supplement the Walker classification system (F & D)?

- e.g. most eruptions are not of a single type
- e.g. great variety in explosive basaltic volcanism (simultaneous fountaining and collapse)**:** does it need its own terminology?

→ Possible additional descriptive parameters to better characterize deposits and their variability (cf petrology: bubble number density and size, microlite sizes and shapes…)

→ Classification using dynamics inferred from geophysical data (e.g. Vulcanian vs. Strombolian, cf. Marchetti et al. 2009)? How to generalize it? More info needed for large energy eruptions

→ Need to identify mechanisms before naming

- **"open" vs. "closed" system:** different meaning from remote sensing and petrology communities

- **In situ production of ash by clast break-up**

Pyroclastic Density Currents

Deposits of PDC

- **Particle parameters we should measure:** size, density, internal and basal friction coefficient, coefficient of restitution, roundness, heat transfer capacity, porosity, bulk bed permeability, etc…

- **What is the representative grain size range?** (i.e. the range that is likely to control the whole flow dynamics)

- **Grain size distribution varies with time in the parent flow:** cf. loss (elutriation, deposition) and gain (in situ production by breakage and collisions, entrainment of the substratum)

- **PDC deposits are not snapshots of parent flows and cannot be inverted based on our present knowledge** (especially for dense flows), in contrast to plumes

- **Need to revisit "famous" deposits?** (Taupo, etc…)

Structure and dynamics of PDC (1)

- **4D variations → complex flow structure**

Vertical and lateral variation of particle concentration and type/degree of interactions between particles and/or with the substrate

- **In many cases: "dense" basal avalanche + "dilute" ash cloud**

- **"dilute" vs. "dense":** need to define a threshold particle concentration?
- factors favoring **decoupling processes** (cf. flow in valleys, entrainment…)
- **relative volume** of avalanche and cloud? (influences on whole flow dynamics)
- **transition:** sharp or gradational?
- **basal avalanche:** commonly fines-rich (cf. no/weak turbulence)
  possibly sliding head (cf. erosion?) + depositional body

- **Possible influence of the nature of the particles:** hard vs. soft (influence on type/degree of particle interactions)

Structure and dynamics of PDC (2)

- **Gas phase:**
  - **degree of gas-particle interactions?** (control on pore fluid pressure)
  - **air entrainment?** (may be inferred from deposit temperature?)

- **In situ production of ash:** amount, influence on permeability (and hence pore fluid pressure)

- **Influence of the mode of eruption? (column/boiling over):** single/ multiple events, role of a ring-fracture?

- **Interaction with the substratum**
  - **flow in valley:** basal avalanche may overspill or decouple from cloud
  - **erosive power of the current** (cf. field evidence): amount of material incorporated ?

Monitoring of PDCs

- **To gain information on:**
  - modes of generation of PDCs (near vent studies)
  - factors influencing PDC dynamics: particle size and concentration

- **Applicable remote sensing tools**
  - infrared cameras: study of thermal gradients & dynamics
  - Doppler radar to determine grain size: applicability?
  - seismometers/infrasound: possibility to extract useful information on flow dynamics from the signals (e.g., Ripepe et al., EOS, 2009)?

- **Focus on target volcanoes?** (Colima, Merapi, Montserrat, etc…)

Experiments on PDC

- **Two types and aims**

  - "Exploratory" experiments:
  - **simple experiments** with controlled parameters
  - insights into the **basic dynamics**: kinematics, deposition
  - highly concentrated **fines-rich gas-particle flows** behave as **inertial fluid flows** (cf. high pore fluid pressure)

  - "Parametric" experiments:
  - to **test theory**
  - to **get input parameters** for numerical models

- **Need for**

  - high velocity (high Re) experiments on dilute flows

  - large-scale (10's m) experiments: to overcome some scaling issues, possibility to use monitoring techniques

- studies on **particle segregation processes**

Numerical modeling of PDC

- **Multiphase flow models are powerful tools**
  - combine both fluid and solid mechanics, powerful to simulate concomitant dense basal avalanche and dilute ash cloud
  - too many input parameters?, what is the maximum critical particle concentration to treat turbulent flows?

- **Good Digital Elevation Models required**
  - what is "good"? (i.e. optimal resolution)

- **Fundamental issues**
  - **type of friction law** for dense flows: cf. granular-type (importance of pore fluid pressure) vs. fluid-type
  - **degree of particle-particle and gas-particle interactions**

- **Useful parameters for models:** flow runout, volume, and inundation area; (mean) mass flux; topography (DEM); particle grain size range (size max. useful to infer flow dynamics), gas content

Hazard maps of PDC: uncertainty and probabilistic methods

- **Two objectives :**
  - for hazard assessment
  - for understanding processes

- **Uncertainty of inputs:** to what extent are the maps to be trusted?

- **Digital Elevation Models:** should we request the authorities to produce really good (cm precision) DEM?

- **Possibility to use probabilistic methodologies** (same as for plumes?)

But output needs to remain clear, simple and unambiguous so as to be used for rapid and effective communication to the hazard manager and public

Future steps

- **V-HUB :** Cyberinfrastructure for collaborative research and integration of numerical models with observational and experimental data (led by U. Buffalo)

- **Cities on Volcanoes 6, Tenerife, 31 May - 4 June 2010**

- **CMG, Pisa, 7-11 June 2010:** 28th IUGG Conference on Mathematical Geophysics, Modelling Earth Dynamics: Complexity, Uncertainty and Validation

- **IUGG Melbourne, Australia, 2011:** interdisciplinary sessions

- **Synthetic/perspective article** of the IAVCEI Commission on Explosive Volcanism in EOS