Chapter 102
Validation Approaches to Volcanic Explosive Phenomenology

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ABSTRACT

Large-scale volcanic eruptions are inherently hazardous events, hence cannot be described by detailed and accurate in situ measurements. As a result, volcanic explosive phenomenology is poorly understood in terms of its physics and inadequately constrained in terms of initial, boundary, and inflow conditions. Consequently, little to no real-time data exist to validate computer codes developed to model these geophysical events as a whole. However, code validation remains a necessary step, particularly when volcanologists use numerical data for assessment and mitigation of volcanic hazards as more often performed nowadays. We suggest performing the validation task in volcanology in two steps as followed. First, numerical geo-modelers should perform the validation task against simple and well-constrained analog (small-scale) experiments targeting the key physics controlling volcanic cloud phenomenology. This first step would be a validation analysis as classically performed in engineering and in CFD sciences. In this case, geo-modelers emphasize on validating against analog experiments that unambiguously represent the key-driving physics. The second "geo-validation" step is to compare numerical results against geophysical-geological (large-scale) events which are described —as thoroughly as possible— in terms of boundary, initial, or flow conditions. Although this last step can only be a qualitative comparison against a non-fully closed system event —hence it is not per se a validation analysis—, it nevertheless attempts to rationally use numerical geo-models for large-scale volcanic phenomenology. This last step, named "field validation or geo-validation", is as important in order to convince policy maker of the adequacy of numerical tools for modeling large-scale explosive volcanism phenomenology.

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1. INTRODUCTION

Large-scale explosive volcanic eruption cloud is one of the most enthralling yet hazardous phenomena one can witness in Nature (see Figures 1 and 2). Such catastrophic events potentially pose a major threat to human life, livestock, the environment at large, and aircraft safety. They can also potentially disrupt all social and economical activities for many years after the eruption. Typically, these volcanic clouds consist of hot magmatic fragments and lithic clasts dispersed in a carrying gas phase. Initially, this hot multiphase mixture is expelled subvertically from a volcanic vent at speeds up to a few hundred of seconds and with densities greater than the surrounding atmosphere (negative buoyancy). As this momentum-driven jet "thrusts" upwards into the atmosphere, it expands, hence dilutes itself and decreases its own bulk density *w.r.t.* the ambient atmosphere. Consequently, the jet becomes a buoyancy-driven plume (*Valentine, 1998; Dartevelle et al., 2004; Dartevelle, 2005*). The exact fate of this buoyant plume will be controlled by a balance between three major forces, *viz.*, (1) the buoyancy force, which pulls the cloud upward to higher altitudes, (2) the gravity force, which exerts a downwards pull, and (3) turbulence, which has an overall dissipative effects on the clouds and slows it down (this is often characterized as the "atmospheric drag" effect). In addition to the natural dissipative effects, turbulence may also have important supplementary non-linear effects upon the rising plume. For instance, turbulence causes important entrainment of atmospheric "fresh" ambient into the volcanic dusty cloud. As such, turbulence further dilutes the flow, which potentially increases its buoyancy; yet, at the same time, turbulence entrains colder air into the cloud, which decreases the buoyancy of the plume *w.r.t.* atmospheric ambient (*Dartevelle et al., 2004*). Hence, either the plume further rises to higher altitudes till it exhausts its excess of buoyancy and radially spreads like a gigantic mushroom (the cloud is named "plinian"), or the plume is not buoyant enough and collapses back to the ground forming destructive high-velocity hot ash-and-gas avalanches propagating around the volcano (these avalanches are named "pyroclastic" flows and surges) (*Valentine and Wohletz, 1989; Druitt, 1998; Dartevelle et al., 2004; Dartevelle, 2005*).

Figure 1. Mt. Pinatubo volcanic jet, Philippines, 12 June 1991. Altitude: ~12 km. Notice the well structured underexpanded jet and the proto-developed turbulent plume above the jet.

Figure 2. Ascending eruption cloud from Redoubt Volcano. View is to the west from the Kenai Peninsula. Notice that the main plume is offset from the vent. Altitude: ~10 km. (Photograph by J. Warren, April 21, 1990, USGS).

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