Chapter 13
Validation Approaches to Volcanic Explosive Phenomenology

Sébastien Dartevelle
Los Alamos National Laboratory, USA

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.

DOI: 10.4018/978-1-61520-651-3.ch013

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*). The whole phenomenology can last from a few minutes to a few hours and covers spatial scales from a few kilometers to tens of kilometers.

Since the pioneer works of volcanologists from Los Alamos National Laboratory (*Wohletz et al., 1984;Valentine and Wohletz, 1989;Valentine et al., 1991*), multiphase codes have been used more and more often to capture the whole volcanic phenomenology (*e.g.*, *Dobran et al., 1993;Neri et al., 2003;Oberhuber et al., 1998;Dartevelle et al., 2004;Suzuki et al., 2005*), yet with little evidences that the produced numerical results accurately capture the physics of these eruptions. So far, numerical "validation" in volcanology tends to be more qualitative rather than to be a true quantitative and rigorous validation analysis, as one would expect. However, because of the enormous scale of the event and its rather destructive and lethal nature, only afar and indirect methods can be used to infer some information about their dynamic and physical properties (*e.g.*, with satellite remote sensor, photographic methods, acoustic pressure sensors, *etc.*). Consequently, little is known about the exact dynamic of these gigantic volcanic clouds and too little data can be usefully used to validate computer codes (*Dartevelle et al., 2004*). Yet, more and more often, these codes and numerical results are used for assessing volcanic hazards and for mitigating the associated volcanic risks (*e.g.*, *Todesco et al., 2002; Esposti et al., 2002;Dartevelle and Valentine, 2005,2008*). Without any thorough validation studies, one may question the intrinsic value of such invalidated numerical studies. Validation studies are needed; not only volcanologists would gain more confidences in their newly developed numerical tools but would also be empowered to better convince policy-makers of the usefulness of their approaches to mitigate potential volcanic hazards.