An analysis of the relationship between mass eruption rate and runout distance of pyroclastic density currents

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Explosive volcanic eruptions generate buoyant plumes that rise into the atmosphere to form umbrella ash clouds. In many cases, variations in source parameters during eruptions cause the plumes to turn into collapsing fountains, which generate ground-hugging pyroclastic density currents. It is well known from previous work that the plume height increases with the mass eruption rate. A similar relationship for pyroclastic density currents, relating their runout distance to the eruption rate, has been suggested by some authors but remains to be quantified from a large dataset. In this context, we compiled the data of 39 well-documented eruptions of small (<0.01 km^3) to large (>1000 km^3) volumes, with eruption rates (Q) and flow runout distances varying by five and two orders of magnitude, respectively. The eruption rates given in literature are obtained by three different means. Most data are reported for the plume phase and are derived from the height of the column determined from isopleths of the fall deposits (Q_h). Eruption rates are also given for the current phase, either from the ratio of the volume to the duration of the flows (Q_v) or from models of the pyroclastic currents and their overriding ash clouds (Q_m). A first analysis of the cases for which different types of eruption rates were known showed that Q_m (cf. current phase) was one order of magnitude higher than Q_h (cf. plume phase). This is in agreement with previous work, and it may be interpreted in terms of conduit enlargement due to erosion and/or onset of caldera collapse with opening of multiple vents or ring-fractures. When only Q_h was known for a given eruption, we have therefore taken into account corrected (larger) values of Q_h in our database to quantify the relationship between the eruption rate and the runout distance of the currents. We found also that the values of Q_v (cf. current phase) were in general closer to those of Q_m than to those of Q_h. Then, based on authors interpretations of flow deposits and on recent quantitative advances, we considered end-member, dominant transport mechanisms of particles within the currents. We thus distinguished between fully dilute turbulent currents (at Q up to 10^{10} kg/s) and basal concentrated flows with an overriding ash cloud (at Q up to 10^{12} kg/s). The results highlight two distinct trends with coefficients of determination of 0.92-0.93: the runout of dilute and dense currents increases with $Q^{0.47}$ and $Q^{0.38}$, respectively. At given eruption rate, dilute currents have longer runouts than dense ones, but the longest runouts >100 km are those of dense flows driven by the highest eruption rates. Similar trends are found also for the runout as a function of the volume of the flow deposits, because the latter correlates positively with the eruption rate, but with lower coefficients of determination of ~0.80. Our analysis suggests that the mass eruption rate is the main control parameter on the runout of pyroclastic density currents. The trends identified for dilute and concentrated currents are robust and can be used to infer eruption rate from runout when the former is unknown. This is of particular interest when fall deposits are absent.

Keywords: explosive volcanism, eruption rate, pyroclastic density currents, runout distance

