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In-situ production of ash and clast breakup in pyroclastic density currents: model results and a preliminary field validation

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Abrasion and comminution of clasts during the propagation of pyroclastic density currents (PDCs) have long been recognized as a potential source for the enhanced production of volcanic ash. However, the importance of comminution on both ash production and flow characteristics has not been quantified. The amount of ash produced during transport can potentially affect runout distance, deposit sorting, the volume of ash introduced in the upper atmosphere, and internal pore pressure. We develop a numerical multiphase flow model to evaluate the amount of ash produced by particle-particle interactions during transport. The subgrid-scale physics in this model is based on laboratory experiments of particle collisions. We find that for typical pyroclastic density currents, 10-20% of the initial clasts comminute into ash with the percentage increasing as a function of initial flow energy. Most of the ash is produced in the high-energy regions near the vent, although flow acceleration on steep slopes can produce ash far from the vent. On level terrain, this ash generates gravity currents that detach from the main flow and can more than double the effective runout distance. Currents that descend steep slopes produce the majority of their ash in the flow head, and flow snouts likely develop sub-angular to rounded pumice during this process. To test our model predictions we examined the roundness of pumice clasts deposited in pyroclastic density currents at Mount St Helens, Washington and Mount Lassen, California. Because clast comminution should progressively round clasts during transport, we expect a relationship between mass loss and roundness. We first determined experimentally a relationship between mass loss and particle roundness for pumice from both volcanoes. With this empirical calibration, we can relate roundness of clasts in actual deposits to a mass loss and hence to the amount of ash produced. Given the uncertainties in this calibration and the parameters that are used in the numerical simulations, we find good agreement between expected and measured roundness at both volcanoes.