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New insights on the solid phase concentration in dilute volcanic gas-particle mixtures from laboratory experiments

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Volcanic gas-particle mixtures such as plumes and pyroclastic density currents may have a wide range of particle concentrations. This work addresses the dynamics of dilute mixtures in which the particles are carried by the turbulent gas. Though previous studies suggest that such mixtures have particle concentrations of the order of one volume percent, the dependence of the solid concentration with the Reynolds number is unclear. We addressed this issue through laboratory experiments in a vertical tube, where gas-particle mixtures were created by injecting a turbulent air flow. Nearly monodisperse mixtures of glass beads of different grain sizes (77 μm to 1550 μm) were used with varying bulk concentrations from 0.025 to 8 vol. %.
The particles were injected stepwise between runs. To create a quasi-static mixture, the mean air velocity was set to match the terminal particle settling velocity for different grain sizes. Thus air velocities of 0.5-9.6 m/s were used, corresponding to maximum Reynolds numbers of the mixtures of $\sim$104-106. The air pressure indicated full support of the particle weight at concentrations down to 0.025 vol. %. Above a critical particle concentration, subsequent additional particles were not maintained in the mixture and instead led to the formation of clusters that settled to the base of the pipe to form a dense fluidized bed. This critical concentration was determined from the data of the pressure sensors placed along the side of the device. The pressure increased with the particle concentration until the maximum concentration was reached and then the pressure was constant. Maximum particle concentrations of the dilute mixtures laid in between $\sim$0.3-2.8 vol. % and increased with the mixture Reynolds number to the power one-fifth. These results give insights into the maximum particle concentrations of volcanic dilute gas-particle mixtures. However, in further experiments it will be tested if this maximum concentration is volume or mass dependent by using particles of a higher density.