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CrystalMoM: a tool for modeling the evolution of Crystals Size Distributions in magmas with the Method of Moments

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It is well known that nucleation and growth of crystals play a fundamental role in controlling magma ascent dynamics and eruptive behavior. Size- and shape-distribution of crystal populations can affect mixture viscosity, causing, potentially, transitions between effusive and explosive eruptions. Furthermore, volcanic samples are usually characterized in terms of Crystal Size Distribution (CSD), which provide a valuable insight into the physical processes that led to the observed distributions. For example, a large average size can be representative of a slow magma ascent, and a bimodal CSD may indicate two events of nucleation, determined by two degassing events within the conduit.

The Method of Moments (MoM), well established in the field of chemical engineering, represents a mesoscopic modeling approach that rigorously tracks the polydispersity by considering the evolution in time and space of integral parameters characterizing the distribution, the moments, by solving their transport differential-integral equations.

One important advantage of this approach is that the moments of the distribution correspond to quantities that have meaningful physical interpretations and are directly measurable in natural eruptive products, as well as in experimental samples. For example, when the CSD is defined by the number of particles of size D per unit volume of the magmatic mixture, the zeroth moment gives the total number of crystals, the third moment gives the crystal volume fraction in the magmatic mixture and ratios between successive moments provide different ways to evaluate average crystal length. Tracking these quantities, instead of volume fraction only, will allow using, for example, more accurate viscosity models in numerical code for magma ascent.

Here we adopted, for the first time, a quadrature based method of moments to track the temporal evolution of CSD in a magmatic mixture and we verified and calibrated the model again experimental data. We also show how the equations and the tool developed can be integrated in a magma ascent numerical model, with application to eruptive events occurred at Stromboli volcano (Italy).