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Settling of crystals with variable density and size in turbulent convection

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Abstract

Early differentiation of planetary mantles takes place upon crystallization of magma oceans. The convection of large-scale magma reservoirs is highly vigorous and turbulent. Motion of small crystals in such flow is non-trivial and can be captured by the Maxey-Riley equation (Maxey & Riley, 1983). To what extent turbulent convection affects the fate of suspended crystals is still a matter of debate. Although scaling laws for settling velocities of solid particles exist (see e.g. Solomatov, 2015, and the references therein), these are not confirmed by direct numerical simulations in turbulent regimes at high Rayleigh numbers. Furthermore, the scaling laws do not elucidate the details of the spatial distribution of crystals within a convection cell - e.g. in the numerical work of Park et al., 2018, it was reported that, for a specific range of model parameters, suspended particles tend to cluster at plume edges. Understanding the settling velocities of crystals and crystal clustering during magma ocean solidification is important for understanding the differentiation and initial compositional distribution of planetary mantles.

The relative density difference between newly formed crystals and the residual liquid depends on the pressure, temperature, and the bulk composition of magma. Depending on the stage of solidification, both light crystals in a denser fluid and dense crystals in a lighter fluid can be expected. In this study we perform simulations of highly vigorous (Rayleigh number up to 10^{10}) and turbulent (Prandtl number equal to 1) convection with suspended particles. We vary the density and size of the particles and investigate the rate at which crystals settle and accumulate near the top and bottom boundaries of the model domain. The numerical experiments are performed in 2D Cartesian geometry using a freely available lattice Boltzmann code (https://github.com/ecalzavarini/ch4-project).

References

[Maxey and Riley, 1983] Maxey, M. R. and Riley, J. J.(1983). Equation of motion for a small rigid sphere in a nonuniform flow. *Physics of Fluids*, 26(4) 883-889.

[Solomatov, 2015] Solomatov, V. (2015). Magma oceans and primordial mantle differentiation. *Treatise on Geophysics*, Second Edition, p81-104.

[Park et al., 2018] Park, H. J. and O'Keefe, K. and Richter, D. H. (2018). Rayleigh-Bénard turbulence modified by two-way coupled inertial, nonisothermal particles *Phys. Rev. Fluids*, 3(3): 034307.