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Influence of rotation on iron droplets in an early magma ocean

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Today it is widely accepted that the Earth during its evolution experienced periods where a great part of its mantle was completely molten. In some cases, for example after a 'Giant impact' a so called 'Magma Ocean', i.e. a layer of molten material, extending to a depth of about $1000km$, can form. In this vigorously convecting environment the separation of iron and silicate takes place. Small iron droplets of a size about $1cm$ could have formed and fall, due to their higher density through the molten silicate to the bottom of the magma ocean. This scenario is called the 'Metal Rain Scenario'. It is the first step in the core forming processes of the Earth. We employed a 3D Cartesian numerical model with finite Prandtl number, in order to study the sinking of heavy particles in a vigorously convecting environment. Differently from most approaches we have included the effect of rotation on the flow dynamics. Due to the low viscosity of the magma ocean and a much faster rotation of the Earth at that time the influence of rotation on the fluid flow of the magma ocean can not be easily neglected. Our numerical fluid model is based on a Finite Volume discretization, while the numerical model for the iron droplets based on an discrete element model for the simulation of granular Material. The particles influence the fluid flow through the chemical component of the fluid model, which is the volumetric ratio of the particle in each fluid cell. The particles themselves experience the force of the fluid through the fluids drag. Also gravitational and Coriolis forces act on the particles.

In our present work we study the influence of strong rotation on the iron droplets with a rotation axes parallel to the gravitational acceleration like on the earth pole and with an rotation axes perpendicular to gravity like on the equator. Depending on the strength of rotation we find a different behavior of the particles. For the poles the particles fall nearly with Stokes' velocity to the bottom. But for the equatorial region the particles can stay suspended depending on the strength of the Coriolis force acting against gravity. We find three regimes depending on the strength of rotation for the equatorial case. At low rotation rates the particles fall to the bottom similar to that at the poles. At higher rotation rates the particles stay suspended in the bottom 1/3 of the box and have an insulating effect on the hot thermal boundary layer. At high rotation rates the particles are completely suspended in a ribbon in the middle of the box.

If the high rotation rate scenario was true for the magma ocean on the Earth it could be possible that a small amount of iron was suspended in the mantle after the core formation. This could lead to a better explanation for the overabundance of siderophile elements. If the trapped iron still exists today in the mantle it may also be observable through seismological studies.