CHALLENGES IN MODELLING MAGMA OCEAN EVOLUTION USING A 1-D ATMOSPHERE-INTERIOR COUPLED MODEL FOR THE EARLY EARTH

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The early phases of the evolution of the Earth and terrestrial planets have been likely characterised by one or multiple vigorously convecting magma oceans. Even super earths at a close distance to their host star can presently be in a similar condition. Understanding magma ocean evolution can serve to better characterise the evolution of the Earth and of terrestrial bodies that experienced a magma ocean state in their early history.

The evolution of a vigorously convecting magma ocean is poorly known due to the paucity of constraints from the geological record and to the difficulty of assessing the mechanical and thermal properties of molten and partially molten materials at the extreme conditions of a magma ocean. The evolution of the potential temperature dictates the rate of mantle crystallization of the interior, which likely proceeds from the bottom upwards because of the steeper slope of the mantle adiabat compared to the solidus. A challenging factor is the extreme parameter range of the regime of thermal convection. The dynamic viscosity of silicate liquids is expected to be of the order of $10^{-3} Pa\, s$, which implies Rayleigh and Prandtl numbers of $\sim 10^{30}$ and ~ 1, respectively. This makes it presently impossible to tackle the problem with direct numerical simulations and thus requires the use of parametrised models. The intense delivery of volatiles with greenhouse potential from the interior to the atmosphere adds another level of complexity to the overall energy balance. The resulting atmosphere could be deviating from the radiative two-stream approximation that is widely used in the earth system modelling, by possibly activating more atmospheric windows in the optical range of the spectra, and by being in the supercritical regime of water vapour.

Using a simple 1-D model we simulate the evolution of a primitive magma ocean coupled with a grey atmosphere, based on the work of Lebrun et al. (2013) [1]. Comparing cases with and without atmospheric coupling, we show that the atmosphere generated by magma ocean degassing, which is rich in greenhouse gases, can strongly retard the cooling and solidification time of the interior by up to a few million years.

In order to monitor the planetary cooling rate during the lifetime of the magma ocean and its co-evolving atmosphere, there is room for improvement in the coupling of the two systems. This approach could benefit from a close interaction between the interior dynamics and climate modelling communities and from the contribution of novel experimental data covering a broader range of parameters.

References

[1] T. Lebrun, H. Massol, E. Chassefière, A. Davaille, E. Marcq, P. Sarda, F. Leblanc and G. Brandeis, *Thermal evolution of an early magma ocean in interaction with the atmosphere*, J. Geoph. Res. and Planets **118**, 6 (2013).