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Ganymede's core in the Fe-snow regime: The influence of latent heat on the chemical gradient

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Some years ago it was proposed [1,2] that solidification processes in cores of small planetary bodies such as Ganymede may significantly differ from the Earth-like core regime. In the case of Earth iron solidifies at the core center as a result of cooling. Looking at cores in the low pressure regime ($\approx$ 6 to 10 GPa) the iron will rather solidify at the core-mantle boundary. This difference originates from negative slopes of the melting curve of iron-rich Fe-FeS alloys in the low pressure range [3,4]. Since the iron is gravitationally unstable it will sink down towards deeper core regions, where it will remelt again due to higher temperatures. The result is a chemical gradient evolving across the core regions, in which iron precipitates. The chemical gradient may have influence on the generation of magnetic fields in such small planetary bodies. On the one hand it affects the ability of core cooling and on the other hand the process of snowing iron could serve as an own mechanism for generating magnetic fields.
We investigate the thermal evolution of Ganymede's core in the Fe-snow regime. The model accounts for the solidification of iron, where we assume thermo-chemical equilibrium, and the subsequent redistribution of iron to deeper core regions. We focus on the effect of latent heat associated with freezing and melting processes, which has so far been neglected in earlier models [1]. Own previous studies showed that heat transport by convection may not be feasible in the Fe-snow regime due to the large chemical gradients. Thus we consider the two extreme cases of conductive as well as convective heat transport resulting in a conductive and adiabatic temperature profile, respectively. We find that for both temperature profiles the effect of latent heat reduces the chemical gradient. But nevertheless the chemical gradient is still large enough to impede thermal convection. Looking at the timescales of the Fe-snow regime until an inner core starts to grow, all models tested here need considerably more time than those models evaluated in [1].

References

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