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Mercury's thermal evolution and core crystallization regime

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Abstract

Unlike the Earth, where the liquid core isentrope is shallower than the core liquidus, at the lower pressures inside Mercury's core the isentrope can be steeper than the melting temperature. As a consequence, upon cooling, the isentrope may first enter a solid stability field near the core mantle boundary and produce iron-rich snow that sinks under gravity and produces buoyant upwellings of iron depleted fluid. Similar to bottom up crystallization, crystallization initiated near the top might generate sufficient buoyancy flux to drive magnetic field generation by compositional convection.

In this study we model Mercury's thermal evolution by taking into account the formation of iron-rich snow to assess when the conditions for an internally magnetic field can be satisfied. We employ a thermodynamic consistent description of the iron high-pressure phase diagram and thermoelastic properties of iron alloys as well as the most recent data about the thermal conductivity of core materials.

We use a 1-dimensional parametrized thermal evolution model in the stagnant lid regime for the mantle (e.g. [1]) that is coupled to the core. The model for the mantle takes into account the formation of the crust due to melting at depth. Mantle convection is driven by heat producing radioactive elements, heat loss from secular cooling and from the heat supplied by the core.

The heat generated inside the core is mainly provided from secular cooling, from the latent heat released at iron freezing, and from gravitational energy resulting form the release of light elements at the inner core-outer core boundary as well as from the sinking of iron-rich snow and subsequent upwellings of light elements in the snow zone. If the heat flow out of the core is smaller than the heat transported along the core isentrope a thermal boundary will from at the top of the outer core. To determine the extension of the convecting region inside the liquid core we calculate the convective power [2]. Finally, we use the entropy budget of the core (e.g. [3]) together with the core mantle boundary heat flow to assess whether a magnetic field can be generated and sustained inside Mercury's core.

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