Application of the mixed length theory to assess the generation of melt in internally heated systems

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The thermo-chemical evolution of a planetary mantle is fundamental to understand the past and current state of the whole planet. This evolution is however complex because characterized by several complexities. One of the major issue to model mantle evolution is to account for their chemically heterogeneous nature. Indeed, melting of rocks and its associated volcanism induce chemical differentiation producing rocks with a large range of chemical compositions. A robust description of the chemical differentiation would require to track each element compounds and consider their partitioning between solid and liquid. This feature is not yet implemented in 3D numerical codes because it would require heavy computational resources.
Alternatively, we propose a new analytical framework allowing to estimate the amount and depths of melting in 1D parameterized convection. To do so, we develop an approach, partly based on an extended version of the mixed length theory, able to estimate the distribution of the hottest temperatures in natural systems. Due to the novelty of the approach, we apply our framework to a simplified convective system consisting of a purely internally heated fluid in a Cartesian geometry. The approach involves several free parameters that are calibrated by fitting 3D numerical simulations. We then successfully compared the amount of melting estimated from our 1D analytical approach to results of 3D numerical simulations. Building on this success, we develop an algorithm able to calculate the 1D thermal evolution of our convective system including the effect of melting on the heat budget. We then apply our algorithm to the long-term evolution of a generic planetary mantle and compare to the evolution calculated with 3D numerical simulations.

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