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A benchmark initiative on mantle convection with melting and melt segregation

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In recent years a number of mantle convection models have been developed which include partial melting within the asthenosphere, estimation of melt volumes, as well as melt extraction with and without redistribution at the surface or within the lithosphere. All these approaches use various simplifying modelling assumptions whose effects on the dynamics of convection including the feedback on melting have not been explored in sufficient detail. To better assess the significance of such assumptions and to provide test cases for the modelling community we initiate a benchmark comparison. In the initial phase of this endeavor we focus on the usefulness of the definitions of the test cases keeping the physics as sound as possible. The reference model is taken from the mantle convection benchmark, case 1b (Blanckenbach et al., 1989), assuming a square box with free slip boundary conditions, the Boussinesq approximation, constant viscosity and a Rayleigh number of 1e5. Melting is modelled assuming a simplified binary solid solution with linearly depth dependent solidus and liquidus temperatures, as well as a solidus temperature depending linearly on depletion. Starting from a plume free initial temperature condition (to avoid melting at the onset time) three cases are investigated: Case 1 includes melting, but without thermal or dynamic feedback on the convection flow. This case provides a total melt generation rate (qm) in a steady state. Case 2 includes batch melting, melt buoyancy (melt Rayleigh number Rm), depletion buoyancy and latent heat, but no melt percolation. Output quantities are the Nusselt number (Nu), root mean square velocity (vrms) and qm approaching a statistical steady state. Case 3 includes two-phase flow, i.e. melt percolation, assuming a constant shear and bulk viscosity of the matrix and various melt retention numbers (Rt). These cases should be carried out using the Compaction Boussinseq Approximation (Schmeling, 2000) or the full compaction formulation. Variations of cases 1 – 3 may be tested, particularly studying the effect of melt extraction. The motivation of this presentation is to summarize first experiences, suggest possible modifications of the case definitions and call interested modelers to join this benchmark exercise.

References:

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