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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 carry out a benchmark comparison. The reference model is taken from the mantle convection benchmark, cases 1a to 1c (Blankenbach et al., 1989), assuming a square box with free slip boundary conditions, the Boussinesq approximation, constant viscosity and Rayleigh numbers of 10̂4 to 10̂6. Melting is modelled using 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) five 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 is identical to case 1 except that latent heat is switched on. Case 3 includes batch melting, melt buoyancy (melt Rayleigh number Rm) and depletion buoyancy, but no melt percolation. Output quantities are the Nusselt number (Nu), root mean square velocity (vrms), the maximum and the total melt volume and qm approaching a statistical steady state. Case 4 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 are carried out using the Compaction Boussinseq Approximation (Schmeling, 2000) or the full compaction formulation. For cases 1 – 3 very good agreement is achieved among the various participating codes. For case 4 melting/freezing formulations require some attention to avoid sub-solidus melt fractions. A case 5 is planned where all melt will be extracted and, reinserted in a shallow region above the melted plume. The motivation of this presentation is to summarize first experiences and to finalize the case definitions.

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