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Influence of magmatism on mantle cooling, surface heat flow and Urey ratio

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Two-dimensional thermo-chemical mantle convection simulations are used to investigate the influence of melting-inducted differentiation on the thermal evolution of Earth's mantle, focussing on matching the present-day surface heat flow and the 'Urey ratio'. The influence of heat production rate, initial mantle temperature and partitioning of heat-producing elements into basaltic crust are studied. High initial mantle temperatures cause major differences in early mantle thermo-chemical structures but by the present day surface heat flux and internal structures are indistinguishable from cases with a low initial temperature. Assuming three different values of mantle heat production that vary by more than a factor of two results in small differences in present-day heat flow, as does assuming different partitioning ratios of heat-producing elements into crust. As a consequence of the model present-day surface heat flow varying only slightly with parameters, the Urey ratio is highly dependent on the amount of heat production, and due to the large uncertainty, the Urey ratio is considered to be a much poorer constraint on thermal evolution than the heat flow. The range of present-day Urey ratio observed in simulations here is about 0.3 to 0.5, which is consistent with observational and geochemical constraints [Jaupart et al., 2007]. Magmatic heat transport contributes about 10% to Earth's present-day heat loss but a much higher fraction at earlier times — often more than convective heat loss — so neglecting this causes an overestimation of the Urey ratio. Magmatic heat transport also plays an important role in mantle cooling. Considering these points, it is important to include magmatic effects when attempting to understand the thermal evolution of the Earth. In addition, we will show some preliminary results on thermal evolution of Earth's mantle and core including additional compositional anomalies at the base of mantle known as the BAsal Melange 'BAM' [Tackley, 2012].