Effects of stably stratified region below the core-mantle boundary on the long-term core-mantle evolution

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Here we show an impact of stably stratified region below the core-mantle boundary (CMB) caused by the core-mantle thermo-chemical coupling in long-term core-mantle evolution model in numerical mantle convection simulations. To implement the core-mantle thermo-chemical coupling into the model, we assume chemical and baro-diffusion effects caused by an equilibrium chemical reaction of metal-silicate as a boundary condition of thermo-chemical structure of Earth's core based on Frost et al. [2010]. In addition, we also include the growth of sub-adiabatic shell if the CMB heat flow is below the isentropic heat flow. Using this model, important findings are shown as follows: 1. The initial CMB temperature would be 4800 to 4900 K rather than 6000 K derived from thermal evolution model without a stably stratified region. 2. Thickness of thermo-chemically stratified region would be strongly dependent of chemical diffusivity and 140 km with 10^{-8} mˆ2/s of chemical diffusivity, which would be consistent with propagation of MAC wave caused by geomagnetic secular variation for the thickness [Buffett, 2014] and theoretical computation of chemical diffusivity [Ichikawa and Tsuchiya, 2015], 3. The CMB temperature would be rapidly cooled down in first 100 Myrs and not changed after such a rapid cooling, which would be around 4000 to 4200 K. On the CMB heat flow, it would not be greatly changed with time neither, which is around 12 TW being consistent with recent theoretical formulation of core evolution [Labrosse, 2015]. Those evolution diagnostics would be consistent with a recent hypothesis on core evolution from melting temperature measurement in the deep mantle [Andrault et al., 2016]. This suggests that a stably stratified region caused by thermal and chemical effects would be the strongest heat buffer in various mechanisms on heat buffer for heat transfer across the CMB (partially molten region and compositional anomalies above the CMB). 4. The most important physical property for understanding core evolution is the thermal conductivity of Earth's core. For the best-fit scenario of core evolution with a stably stratified region, the thermal conductivity of core would be higher than 150 W/m/K, which is consistent with recent inferences from the electrical resistivity of core material on high P-T physics [e.g. Ohta et al., 2016].